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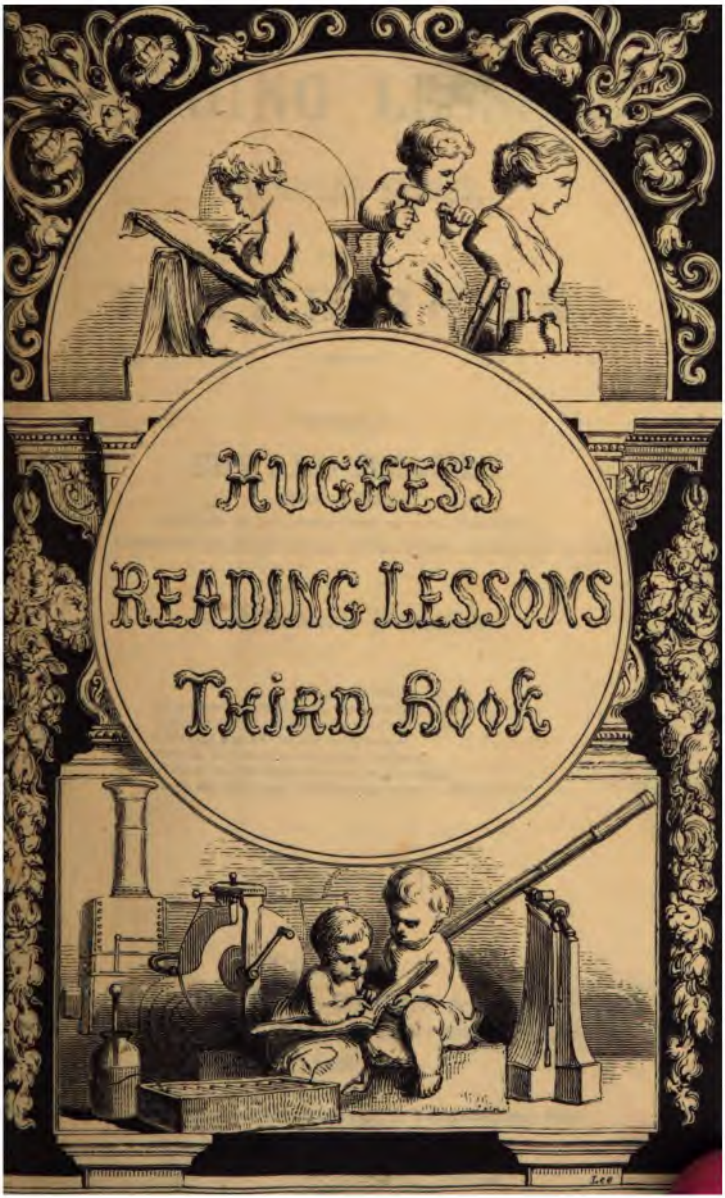
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PREFACE.

In publishing the Third Volume of this series, the Editor gladly takes the opportunity of thanking the public, and more particularly his fellow-labourers, for the liberal support they have given him, in his efforts to introduce a class of useful and instructive reading-books into our system of education. The success of the two previous volumes has fully equalled his most sanguine expectations, and affords a gratifying proof, that he was not mistaken in supposing, that a work containing sound scientific instruction, written specially for youth by authors of eminence, would be acceptable to all teachers and parents who are alive to the daily increasing necessity for educational progress. The ordinary reading-books, made up of selected extracts, may be well adapted for teaching mechanical or declamatory reading; but the Editor in the present series has endeavoured to do more, and to supply exercise to the mental faculties, and valuable information in the various branches of natural science. In this attempt he is happy to find that he has at least in some measure succeeded.

E. H.

Royal Naval Schools
Greenwich Hospital,
January 31, 1856.

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LESSON I.

OBSERVATION AND EXPERIMENT.

"Days should speak, and multitude of years should teach wisdom."

1. THERE is no feature in the aspect of nature more striking than the infinite diversity exhibited in the objects and operations surrounding us. Man, with limited powers of invention, repeats in his productions the same forms and means of accomplishing his ends, while the infinite power of the Creator is manifested in the exuberant variety of His works. Each region of the earth produces its peculiar forms of life; each tree and shrub possesses its own properties and appearance; each stone and leaf has impressed upon it some distinguishing mark. When we reflect upon the daily occurrences of life, we find a similar diversity:—each day that passes is unlike any that has preceded it; each historical event has its own special character; each century presents some new features of human existence. If we descend to the most minute forms of nature we still find this absence of sameness: no two blades of grass are precisely similar, each grain of sand submitted to the microscope shows its own peculiarities in form and colour, and it is only by a theoretical assumption that we can represent the ultimate molecules of bodies as uniform in structure.

2. Now this infinite multiplicity of objects and events is so puzzling to the mind, that knowledge would be impossible, unless we had some mode of grouping and

classifying the subjects of our thoughts. We could not retain them in the memory, or refer to them with sufficient distinctness, or convey our meaning to others. Each individual thing and event would require a separate name, so that our language would resemble the Chinese, in which, there being a distinct word for each distinct object, a lifetime is consumed in learning to read and write. It was the perception of this difficulty which led some of the old philosophers to assert that no science could be constructed from particulars—that is, from separate facts, however numerous; and this assertion, properly understood, is not devoid of truth. We must bind our facts in bundles before they will serve for scientific purposes, and support our footsteps in the advance of knowledge; still the facts are the essential things which must be collected separately before these bundles can be formed.

3. We thus see that while classification is the first step in the formation of a science, the collection of facts must of necessity precede their arrangement. Hence the importance of our two modes of truth-collecting—*observation* and *experiment*. These are employed in obtaining a true knowledge of things previous to arrangement, and inserting new discoveries, when possible, under their respective classes. They aid us in this important work, chiefly by tracing the resemblances and differences of objects. As we have seen what great diversity exists in nature, it is manifest that no reason could be assigned for grouping together several things in one class, unless we could trace resemblances amongst a number of individuals; while, on the other hand, were not the differences accurately ascertained, the confusion of totally unlike things would be unavoidable. Our knowledge is, indeed, in a great degree comparative; we know how objects resemble, and how they differ from, each other, much better than what anything is in itself.

4. In observation we apply our faculties in examining a thing as it is, without endeavouring to alter the conditions under which it is presented to us. With a large class of objects, this is all that is possible for us to accomplish: in astronomy, for instance, we cannot apply

any new force or influence to the stars and planets; we must be satisfied with examining them as they are. Yet this mere passive attention bestowed on things and events has been one of the most effective means of extending human knowledge, and enlarging our acquaintance with the characters and productions of the world we inhabit. It requires, it is true, many moral and physical qualities in the individual who pursues it—honesty, perseverance, endurance—but, supported by these, it has rendered vast benefits to the human race.

5. It has secured to us new materials for industry from remote parts of the earth and new openings for commerce; it has made our own all that other nations in the process of ages have either by chance or ingenuity invented. In past times the care of observant travellers enriched Europe by the introduction of Indian cotton, China silk, Arabian coffee, with the innumerable vegetable and animal materials, and manufacturing processes, which now form the great sources of our national wealth. Within the present century, we have seen, in the discovery of gold in Australia, the vast results that may be obtained by individual observation. An inhabitant of this great colony, who had gone to the gold regions of California, was so struck with the resemblance of the district in which the precious metal was found to one in his own country, that he returned to find, in South Australia, gold-fields more productive than those, whose world-extended renown had induced him to seek them across the ocean. Nor is this field of inquiry exhausted; there are doubtless, in foreign countries, many products which would afford useful materials for our manufacturing skill, and valuable additions to the stores of human food. The mineral, vegetable, and animal resources of the earth and ocean cannot be as yet considered completely explored; there must still remain many unknown benefits which a careful and intelligent observer may confer upon mankind.

6. New applications and improvements of the productions of our own land are likely to spring from the same source. A practical mineral surveyor, Mr. Smith, of

Oxfordshire, may be said to have laid the foundation of geology, by pointing out that fossils indicate the identity of strata. Another gentleman of the same name effected a vast improvement in our agriculture by introducing the system of drainage of fields; indeed, it would be impossible to mention any art or manufacture into which observation has not introduced important improvements, and is not likely to introduce others, perhaps of equal value. A man who takes attentive note of all that occurs of interest in his art or profession, acquires the valuable quality of mind called practical experience. An experienced sailor knows the signs of the weather, the sets of currents, and other matters of importance to the safety of the ship, &c.

7. Recording Observations.—In the article, "How to Observe," in the first volume of this series, enough has been said for the student's guidance in the exercise of this important habit; but there is one branch of the subject of great importance not there alluded to, and which requires a few remarks in this place. I refer to the manner of representing our observations and recording them, so as to render them of future service. This may, in the majority of cases, be done by *averages*, *per centages*, or *graphical delineation*.

8. Averages.—When a set of observations of the same kind has been made, it is generally useful to obtain an average of the whole. This is done by dividing the sum of the results by the number obtained. Thus, if the height of the thermometer be observed every hour in the course of a day, the sum of all the degrees of heat, divided by 24, will represent the average or mean temperature of that day. Similarly the sum of all these daily averages, divided by 365, will give the mean temperature of the year. In this manner averages are determined for a great variety of useful purposes, such as corn averages, &c. The average, or, as it is termed from its use in comparing different countries, the relative population of a state, is obtained by dividing the total population by the number of square miles. This process gives for Europe 70 inhabitants to the square mile, and for Australia less than 1.

The system of Life Insurance, so widely and advantageously established in this country, is based upon this principle. Thus if a record be kept of the number of years that each of one hundred men, in ordinary health and strength at thirty years of age, lives after that period, and these years be added together, the sum divided by 100 gives, as the average continuance of human life after thirty, a term of 34 years. An insurance company must therefore charge, for insuring a sum upon a life of 30 years, a series of annual payments sufficient, with the interest upon their investment, to produce at the end of thirty-four years, the sum insured for and a fair profit in addition. The experience of the large London companies during many years shows that calculations based upon this average survivorship lead to almost precisely the results anticipated. A sum of from 2*l.* to 2*l.* 10*s.* is found to be the annual payment required for each 100*l.* insured for on a life of 30 years.

9. Per Centages.—Another convenient mode of representing our observations is that of per centages: thus, in the returns of deaths from disease, or in battle, and in the statistics of education and distribution of industrial occupations amongst a population, we find the facts often arranged as so many per cent. out of the whole. This is, of course, only a relative mode of representing a fact. If, for instance, we read that the deaths in London were in a particular week 3 per cent. of the population, we do not from this know the actual number of persons who died within the time, although, knowing what the population is, this, if required, can be easily found. The way to estimate the per centage, is to multiply the number of cases by 100, and divide the result by the number out of which they were taken. Thus, if, out of a regiment of 1125 men, there be an actual loss of 75, the casualties are 6·6 per cent. This method of representing results supplies the best possible means of comparing the condition of society at different periods, or in different countries. Applying it to education, we find that in England and Wales, in 1851, the number per cent. of children between the ages of seven and fourteen years of age at school was 50, and

in Prussia, in 1843, was 77 (the number estimated upon good authority). It is manifest, from a comparison of these two numbers, that education is more cared for amongst our German neighbours than at home.

10. GRAPHICAL DELINEATION.—By this method the results of a number of observations can be presented before the eye in one glance. We have before seen how the mean annual temperature of a place may be determined; we can still further extend this mode of proceeding, by drawing an irregular line through all the places upon the earth's surface which have been found to enjoy the same mean annual temperature, and form in this way a number of *isothermal* lines, showing the general distribution of heat over the globe. In a similar manner a series of stations has been established for observing the distribution of magnetic force, and lines of equal dip and equal deviation marked down in conformity with the results. The distribution of vegetable and animal life is depicted in the same manner, by lines passing through the observed boundaries of each species. All these lines are of course strictly true only for the points where observations have been actually made, for all intermediate positions they must be considered approximate only; but the greater the number of places is, at which observations have been made, the more closely will these lines approximate to the truth; so that, in time, by increasing the observations, a great degree of accuracy may be obtained. This mode of graphical exhibition of results often leads to important discoveries. Thus, Kepler, having marked down a number of points having the same positions relative to a fixed point that a planet had at successive periods been observed to have towards the sun, found that the line which joined the points was nearly an ellipse, and so was able to announce to the world his great law of the elliptic orbits of the planets.

11. When two elements, as, for instance, time and amount, have to be exhibited, a slightly-different arrangement is made. First, a horizontal straight line is divided into equal parts, to represent intervals of time, and at each division a perpendicular line is raised equal to the number

of degrees or amount observed. The upper extremities of these lines being then connected, the resulting curve shows the progressive changes. This is the mode employed for recording the changes of heat, pressure, moisture, &c., occurring in the atmosphere, and the performance of irregularly-working machines. If to the moveable index of any machine a pencil be attached, and made to mark upon a slip of paper gradually unrolled by clockwork from a small cylinder, the machine becomes self-recording; and in instruments too delicate to bear the pencil, photography has been brought into successful operation for the same purpose. This method is extensively employed in the meteorological department of the Royal Observatory.

12. Care and honesty in making and recording our observations, of matters that come under the examination of our own senses, will generally be sufficient to secure us against obvious mistakes; but, as there are many *facts*, meaning by this term truths resting upon sensible evidence, which cannot be ascertained by personal inspection, such, for instance, as events in past times or distant countries, we have frequently to depend on observations reported by others. It, therefore, cannot be unnecessary to inquire what conditions we should demand before giving credence to these reported observations.

13. EVIDENCE.—The amount and character of the testimony which we should require in any particular case will, it is manifest, greatly depend upon our judgment of the probability of what is asserted. If a person of ordinary honesty and intelligence tell us that a circumstance naturally of not unfrequent occurrence happened at a particular time and place, we find no difficulty in attaching credit to his statement. As, for instance, I feel no hesitation in receiving a report that there was rain in Paris on a particular day last week. But should an event less probable according to my judgment be reported, I withhold my belief until the evidence is strong enough to outweigh this prior opinion of improbability. Should a traveller, for instance, inform me that rain never falls in a certain district of

South America, I would require much stronger testimony for this fact than for the one mentioned above. Indeed this principle extends so far, that assertions may be made which the mind instantly rejects as impossible, without examining evidence, from a conviction that they are opposed to human reason, or inconsistent with known natural laws. In such cases we will not even entertain the evidence, unless forced upon us by some unimpeachable authority.

14. It is therefore in the report of occurrences different from our daily experience, or opposed to our judgment of probability, or where we suspect the honesty of the reporter, that caution is required in questioning and sifting accounts of events given by others. As assisting in this, the following suggestions may be found useful, although we cannot of course here enter into the nature of evidence in general.

First, then, the evidence should be, if possible, direct. A copy of copy is of no authority by our laws; neither in most cases is hearsay evidence; and, if we kept these two simple rules in view, in ordinary affairs as well as in legal, we would avoid much error and confusion. A told me that he was informed by B who heard from C that he had met a man who told him there were men with tails in Arabia. Such a vague rumour as this scarcely deserves the name of evidence; and yet, by the credulous, stories are often received upon such diluted reports. Each additional reporter seriously weakens the force of the testimony, instead of adding strength to it. A very simple assertion often in this manner swells into a monstrous tale; for a story seldom loses anything in the carriage, but rather, like the snowball, enlarges as it rolls, each narrator adding some embellishment to the account of his predecessor.

15. When we cannot communicate with the original observer, we should be quite sure upon whose authority a report rests. Mr. Everybody is nearly as mischievous as Mr. Nobody; and nothing can be more absurd than the very common remark, 'It must be true because everybody says so.' Often the everybody may be traced up to some obscure individual whose solitary evidence

would be worthless, but from whom spreading out in a circle, it seems to be important only because it is diffused. Amongst ignorant people this tendency to accept a rumour for a truth is a fruitful source of delusion. In our own times, it has led to riots and strikes; and every wellwisher to his country would desire to see our population more thoughtful in sifting evidence before giving credence to vague reports.

16. Having found who the witness is, we should next inquire whether he is competent and disinterested. Does he possess sufficient intelligence and general information to understand the matter about which he speaks? and is he free from all interest in deceiving his auditors?—in fact, is he honest and intelligent? Now, it has been our lot frequently to hear very worthy, honest people, whose integrity we could not doubt, give circumstantial accounts of events we could not believe to be true from want of sufficient confidence in their intelligence to outweigh the prior improbability. The simple natives of South America were astounded by the new monster introduced into their country by the Spaniards, so long as they considered the horse and his rider to compose one animal; and a similar hastiness of conclusion created the centaurs of early Greek story. We should also demand diligence on the part of an observer: he must do all that he can to examine into the reality of appearances, testing them by different senses, and comparing them with prior knowledge, before he is entitled to demand our belief in his reports; and, above all, he should be required to submit his facts totally distinct from his conclusions upon them.

17. EXPERIMENT.—Were we to rest satisfied with what Nature voluntarily exhibits to us, we should indeed procure much valuable and interesting information, but should never attain that mastery over natural objects which it is the prerogative of our reason to secure. We must not be merely passive in the acquirement of knowledge. Much truth is revealed to the inquirer which is hid from the mere listener; and we must cross-examine before we can elicit all the facts. Hence it is that modern science eminently deserves the

name of Experimental Philosophy. It not only examines things as they are, but tries what they might be under altered circumstances and in new combinations.

18. By experiment we mean any *trial* made to ascertain the character and properties of an object, or the extent of a principle amongst a number of individual cases. The first and simplest class of experiments will therefore be closely allied to observation, as it will consist in trying whether a substance, apparently of a particular kind, has really the qualities known to belong to the matter it resembles. Thus, for instance, very accurate imitations have been made of the great gold "nugget," and the celebrated "Koh-i-noor" diamond; but if we weigh the one, or attempt to cut glass with the other, they will be found deficient in these known qualities of gold and diamond. Similarly, imitations of fruits can be easily detected from the real by the smell or taste. This mode of proceeding is of course only a means of ascertaining the presence of a quality already known; for if we had not previously learned the peculiar hardness of the diamond, our finding that a piece of crystal would not cut glass, would not, from this want of power, tell us anything about the nature of the substance.

19. It is, however, of the greatest possible value, now that the leading properties of most of the substances in nature have been ascertained. By it the chemist can tell us the character of any substance presented to him, however it may be disguised, and can inform us of the purity and genuineness of the various articles sold in commerce, or used in manufactures. Indeed, we are all in this way experimenters: we scratch varnished wood if we want to ascertain whether it be a valuable timber or a representation: we strike a wall to know whether it is stone or painted brick: we apply a crystallized substance to the tongue to try whether it is a chemical composition or a mineral: we wet a bit of coloured fabric to try if the colours will stand washing. Some substances we bend when we are in doubt, others we press; some we wet, others we expose to heat; we test the sonorous ring of one, the

hardness of another; some we try to stretch, others to tear. To try what things *are* is the object of this kind of experiment.

20. Often, in a somewhat similar way, experiments are undertaken to ascertain the relative fitness of different materials for a special purpose, and the extent to which their properties may be relied upon. Thus, previous to the construction of the celebrated Tubular Bridge over the Menai Straits, a long course of experiments was entered upon to find out the relative values of wrought and cast iron employed in different ways. By these it was found generally that cast iron is best for bearing a crushing force, and wrought for enduring a strain; and, in accordance with this, the two were most advantageously employed in different parts of the structure. Recently an experiment has been made to manufacture wrought-iron guns, which has failed, from the tendency of the metal to resume its natural, or crystallized, condition when subjected to vibrations. This fact, that iron returns from the fibrous to the crystalline texture, was previously known by the observation of axles of railway carriages, which had become fractured after long use; so that it affords an example of what generally occurs, that observation and experiment, when carefully made, confirm each other.

21. Frequently the purpose of experiment is to determine the extent of a truth, so as to ascertain how far it may be considered a principle applicable to a class, or whether it is only a solitary fact. Thus, it was long observed that an object seen through water appeared displaced; substituting other transparent media for water this was found to be generally true—*i. e.*, an object seen through any transparent substance appears displaced. But on examination it was found not to exhibit equal degrees of displacement, being distorted more or less according to the angle under which it was viewed, even when the same transparent substance was experimented with, and varying for the same angle when different substances were used. A careful comparison of the changes resulting under these different circumstances enabled Snellius to give to the world his

well-known law of refraction, and other observers to determine the refractive powers of different substances.

22. It is a different matter when we wish to find out any hitherto unknown properties in substances which we know, or to discover new substances. Then truth-seeking experiments may be said to commence. The substance must be placed under as many different conditions as the experimenter's ingenuity can devise, and the resulting changes ascertained and compared. It was by patient labour in such a mode of cross-examining natural objects that many of the great truths of natural science have been established. Experience, of course, and acquaintance with all that has been previously discovered about the examined substance will often suggest the best line of inquiry in which to proceed, and save much waste of time and fruitless labour. No one should endeavour to seek for a new truth in a science until he has mastered those established by others, or he will run the risk of much useless toil; and, even supposing him successful, may only re-discover something already known and published by persons better informed than himself. It is a well-known fact that much ingenuity which might have been turned to better account has been thus wasted, from ignorance of the actual progress of science and its applications; and many undoubted *discoverers*, so far as is meant by finding a truth for themselves, have been bitterly disappointed after long labours, and the momentary triumph of success, at finding that their results had been long before anticipated by a former labourer in the same field of investigation.—E. Purcell.

ENTERPRISE.

What though this ancient earth be trod
No more by step of demigod,
Mounting from glorious deed to deed
As *thou* from clime to clime didst lead;
Yet still, the bosom beating high,
And the hushed farewell of an eye
Where no procrastinating gaze
A last infirmity betrays,

Prove that thy heaven-descended sway
Shall ne'er submit to cold decay.
By thy divinity impelled
The stripling seeks the tented field;
Inflamed by thee, the blooming boy
Makes of the whistling shrouds a toy,
And of the ocean's dismal breast
A play-ground,—or a couch of rest;
'Mid the blank world of snow and ice,
Thou to his dangers dost enchain
The chamois-chaser awed in vain
By chasm or dizzy precipice;
And hast thou not with triumph seen
How soaring mortals glide between
Or through the clouds, and brave the light
With bolder than Icarian flight?
How they, in bells of crystal, dive—
Where winds and waters cease to strive—
For no unholy visitings,
Among the monsters of the deep;
And all the sad and precious things
Which there in ghastly silence sleep?
Or, adverse tides and currents headed,
And breathless calms no longer dreaded,
In never-slackening voyage go
Straight as an arrow from the bow;
And, slighting sails and scorning oars,
Keep faith with Time on distant shores?
Within our fearless reach are placed
The secrets of the burning waste;
Egyptian tombs unlock their dead,
Nile trembles at his fountain-head.
Thou speak'st—and lo! the polar seas
Unbosom their last mysteries.
But thou O goddess! in thy favourite Isle
(Freedom's impregnable redoubt,
The wide earth's store-house fenced about
With breakers roaring to the gales
That stretch a thousand thousand sails),
Quicken the slothful, and exalt the vile!—
Thy impulse is the life of fame;
Glad hope would almost cease to be
If torn from thy society;
And Love, when worthiest of his name,
Is proud to walk the earth with thee!

WORDSWORTH.

Geology.

BY J. BEETE JUKES.

LESSON I.

LITHOLOGY.

" Finds tongues in trees, books in the running brooks,
Sermons in stones, and good in everything."

1. THERE is a saying in old books of Natural History, which is adopted by Linnæus, that "Stones grow, vegetables grow and live, animals grow, live, and feel." This saying is untrue so far as "stones" are concerned, if the word "grow" is used in the same sense throughout. The growth of animals and plants is a process altogether different from that by which "stones" or any mineral substances are formed; and the term "growth," as describing an internal and spontaneous increase of substance, could never be properly applied to the formation or increase of the latter.

2. In the chapter of Vol. I., describing "Minerals and Rocks, and their Uses," this subject was touched upon; but we propose now to go into it a little more fully, and describe what was the method by which stones and rocks were formed. To do this fully we shall be obliged also to describe the method by which the external crust of the earth was produced; for we cannot explain the formation of any individual lumps or masses of rock, stone, or earth, without also explaining how all the earthy matter which is anywhere open to our examination over the whole face of the globe came into its present form and condition.

And here a difficulty meets us at the outset, which it is quite right we should overcome before we go any farther. Until the science of geology was properly understood, people naturally imagined that the earth was originally created very nearly as we now find it. Just as, till the science of astronomy was properly understood, they as naturally imagined that the sun went round the earth, instead of the earth round the sun. Neither of these sciences, nor any other of the natural sciences, was made the subject of revelation,

and, therefore, there is nothing in the Bible to enlighten us on these points. Incidental expressions are used therein which seem rather to favour the common notions; but that is to be expected, because we have no reason to suppose that the sacred writers were supernaturally enlightened on such matters, and they therefore necessarily used the expressions which would naturally occur to them. There is nothing in the science of astronomy, or in that of geology, at all opposed to any of the great doctrines of revealed religion, and some of the most pious and most eminent divines of all forms of the Christian religion, without exception, have been, and still are, eminent geologists. When, therefore, we speak of the earth as having passed through many different states, and as having existed as a habitable globe through untold ages anterior to the creation of man, we speak of things which the Bible does not contradict, but simply says nothing about them.

3. Geology does not pretend to explain the origin of the earth. Some people have supposed it once to have existed as a gaseous body, and after that as a mass of molten matter. We will not discuss the question, but we will take the earth as we find it—a globe, the surface of which is composed of land and water,—surrounded by an atmosphere of air producing winds, rains, and snows,—and from the interior of which are here and there vomited forth molten masses of stone called lava, accompanied by cinders and ashes, that produce mountains which we call volcanoes. On the earth in this state there are two principal agencies at work producing new rocks, these agencies are FIRE and WATER.

4. IGNEOUS ACTION.—Suppose we take that of Fire first, as the most striking and obvious.

What happens at the eruption of a volcano? We all know that vast quantities of powder, dust, sand, and ashes are blown out of the interior of the mountain, and fall all over the country round its foot. In some of the tremendous eruptions in the larger volcanoes of the globe these materials have been carried even

hundreds of miles in quantities sufficient to darken the air, and have fallen in quantities sufficient to make a layer of some inches at that distance, and of many feet in the immediate neighbourhood of the mountain.

Streams of molten lava, many hundred yards in breadth, many feet in depth, and many miles in length, have flowed from volcanoes into the lowlands around them, or into the sea near their foot. These streams of lava, when cooled, form masses of dark heavy rock, the upper part of which is often cindery and porous, but the inside and lower portion close-grained or compact, hard, solid stone.

5. The showers of ashes, in like manner, when they accumulate to any thickness, become sometimes compressed below, by the pressure of their own weight, into a compact stone, of greater or less hardness and solidity according to circumstances. Those parts that fall into the sea of course become saturated by its water, and gradually sink to the bottom, forming first mud and afterwards stone. Very often springs, containing the substance called carbonate of lime or perhaps some other mineral matter *in solution*, and which are therefore often called petrifying springs, gain access to these beds of ashes, and aid in binding them together into a firm and solid rock.

On the flanks and in the neighbourhood of volcanoes alternations of these deposits of lava and ashes take place through the lapse of ages, until they form very large masses. The thickness of such accumulations over some parts of Herculaneum, for instance, is more than 100 feet.

6. On examining any great volcanic district, we find that whole mountains, and even great chains and ranges of mountains, are either entirely or in very large part made up of these accumulations; so that we must conclude that these ranges of mountains have been gradually formed by the process of the successive eruption and outpouring, and the consequent piling up, of materials proceeding from the interior of the earth. In other words, we arrive at the conviction that there was a time when these particular mountain masses did

not exist, when their materials were buried in the interior of the earth instead of being heaped up on its surface. Compared with that time therefore all the rocks comprising these volcanic mountains are newly formed, and fresh ones are even now being occasionally added to them before our eyes.

7. When, moreover, we come to travel over the globe, we find many other mountainous regions which are not now volcanic, or at least from which no eruptions nor outbursts of fiery matter have proceeded within the periods of history or tradition, which are yet so obviously made up of lava and ashes that we have no hesitation in attributing to them a volcanic origin.

There are therefore large masses of rock and stone on various parts of the earth's surface which have been formed by the agency of Fire. We shall see presently that we shall have to attribute to the same agency, in rather a different form, still larger and more extensive masses.

8. AQUEOUS ACTION.—Let us now examine those rocks and stones that have been formed by the agency of Water. Water may act in two ways. It may either dissolve mineral matter, as it does salt for instance, or it may wear it away bit by bit. We all know that "constant dropping wears away stones," and we have all seen under spouts or pumps, where the dripping of water has taken place for any considerable time, hollows worn in stones placed underneath them. There are some minerals, like salt, that are easily dissolved by water, some, like carbonate of lime, that can only be dissolved slowly and partially, and when the water contains some acid: others again, like silica and alumina, on which water may be said generally to exert no dissolving power. When, then, water wears away stones, consisting wholly or chiefly of siliceous or aluminous particles, it is clear that it does so not by dissolving but by removing them. Its weight, and motion, and friction gradually loosen and tear asunder the little particles of which such stones are composed, and when loose wash them away.

This action may be called a *mechanical* action, be-

cause the water acts like a machine, the dissolving action may, in like manner, be called a *chemical* action, being one of the many processes familiar to us in chemistry.

9. CHEMICAL.—Now suppose we follow these processes out to their results. The water which has dissolved mineral matter in one place, and under one set of circumstances, may of course be made by an opposite set of circumstances to redeposit it, just as salt dissolved in water may be recovered by causing the water to evaporate. Water, therefore, containing carbonate of lime in solution may deposit it ultimately as limestone. It does this continually in many caverns, on the sides of many springs, in the arches of aqueducts, and along the banks of brooks, in either pendant masses like icicles, or encrusting masses on the ground, or round sticks, stones, and other substances.

10. It is obvious that what we see thus taking place on land, may be still more abundantly occurring at the bottoms of seas and lakes, especially when the purely chemical forces are modified by the actions of life in solidifying mineral matter. All the corals and shells, and multitudes of starfishes, crabs, lobsters, and other marine animals, whose hard parts consist chiefly of carbonate of lime, must derive it from the waters of the sea. Some coral reefs, as those on the north-east coast of Australia, are a thousand miles in length, with an average breadth of fifteen or twenty miles, and a maximum thickness at their outer part of probably, at least, two thousand feet. Every part of this huge mass consists of carbonate of lime, separated particle by particle from the waters of the sea, by the processes of life going on within the bodies of marine animals. All the adjacent seas for hundreds of miles, wherever any particles have been brought up by the sounding-lead from the bottom, are found to be strewed with fine calcareous mud, derived from the waste of these reefs.

We know, then, that in many parts of the globe a purely chemical precipitation of carbonate of lime is taking place, producing varieties of limestone, and we know that at the bottoms of our present seas this precipitation is aided by means of the organic chemistry

of animal life in producing vast deposits of the same substance.

11. Now, all rocks and stones thus formed from mineral matter that has been held in solution by water may be called *chemically-formed rocks*. These may be said to consist of:—

1st. All limestones, or rocks composed of carbonate of lime, including *stalactite*, *stalagmite*, *tufa*, *travertine*, *chalk*, *oolite*, *common limestone*, *statuary marble*, and most other *marbles*. When limestone contains a considerable proportion of carbonate of magnesia, mingled with the carbonate of lime, it is called a *magnesian limestone*, or sometimes a *dolomite*.

2nd. Rocks composed of *sulphate of lime*, commonly called *gypsum*, and locally alabaster or plaster-stone. This substance occurs either compact, when it looks like a white, soft, earthy limestone; or crystalline, when it is often fibrous, pure transparent crystals of it being called *selenite*.

3rd. Rocks composed of chloride of sodium, known as "*rock-salt*;" these occur generally as thick beds associated with clay or marl, the salt being in a rudely crystalline and semi-transparent form, often stained to the colour of the marls with which it is associated.

All these "chemically-formed rocks" have one character in common, namely, that they have frequently a *crystalline structure*, being made up of an assemblage of crystals of their respective minerals, all interlocked one with the other. This crystalline structure is always a proof of the rock having been once fluid, either by its having been dissolved in water or melted by heat.

LESSON II.

MECHANICAL ACTION OF WATER.

"The waters wear the stones."

1. That the mechanical action of water is no less prevalent over the globe, may be shown at once by the abundance of mud, sand, gravel, shingle, or boulders which are found in all rivers, and along all sea-shores. It would be impossible for any one to live for many

years in the neighbourhood of any exposed sea-cliff, however hard the rock of which it is composed, without observing the occasional fall of some mass of rock which had been undermined by the breakers of the sea. Along some coasts, as, for instance, along all the eastern coast of England, this action becomes so strong and rapid that whole fields are carried away within the lives of one generation, and the sites of towns and villages, whose names are mentioned in history, are in some instances as much as three or four miles out at sea. All this waste of land has taken place in consequence of the wearing and tearing action of the breakers, and the carrying off by strong currents of the broken and pounded fragments in the shape of small pebbles, sand, or mud, according to the nature of the material. Any one who will watch the action of breakers at high water, especially during a storm, at the foot of a cliff at which are shingle and round pebbles, will observe how the sea washes and dashes these to and fro, pounding and grinding them together, and often hurling them against the cliffs and rocks, using them like geological hammers to knock corners off them.

2. If we were to trace a large river from its source to its mouth, we should see among the mountain torrents whence it takes its rise, many evidences of its action in the shape of blocks that had fallen from the sides of its ravines, and cuts made, even in hard rocks, by its waters. This wearing action would be especially obvious about cascades and waterfalls, which can often be proved to have cut back their own beds, even miles from the place where they once were. The eating or erosive action of a few pebbles, or even a little sand aided by the moving of water, can often be observed to have acted on a small scale in the beds of rivers or on the sea-shore. Circular holes, like wells, sometimes as much as a yard or two in diameter and three or four yards in depth, may be seen in the hardest rocks, with just a few little pebbles or a handful of sand at the bottom. These holes were formed, by the action of a small whirlpool setting the fragments into circular motion, and thus wearing a hollow in the

rocks by their friction, the sand ground off being washed out; and the continuance of this whirling action, whenever the water passed over them, has gradually deepened the holes, to their present depth.

3. If we followed down the river from the mountains to the lower ground, we should see the large rough blocks gradually succeeded by smaller and more rounded ones; these then passing into pebbles of ever-diminishing size, till they gradually were worn down into sand; and, finally, in the case of such large rivers as the Nile, the Ganges, and the Mississippi, into the finest possible mud. This shows us that the mud ultimately swept out into the sea in such large quantities at seasons of flood, and more or less at other times, is, in fact, only the ultimate result of the process going on in the mountains.

Now, the same action that takes place in rivers has also taken place on sea-coasts, although the removal of the finer particles is there commonly more immediate and direct, and the process cannot be followed out by observation as in the case of rivers.

4. Water, moreover, exerts a great mechanical action both as rain and as ice. Rain, when it falls, carries off directly much sand and mud into the rivers and the sea, and also in several ways—either by loosening or by slowly undermining—contributes to the fall of great masses of rock and earth, and produces those large land-slips which are so remarkable in many localities, along the edge of cliffs and steeply-sloping ground.

5. This loosening action of rain is greatly increased when it is converted into ice, because then all the water in the pores and crevices of rocks, being expanded, rends asunder, with irresistible force, alike the smallest particles and the largest masses. On mountains where glaciers are formed, these, as they flow down the valleys from the snow-clad heights to the lower and warmer regions where they melt away, not only grind and wear away the rocks in their passage, but also carry forward all the blocks and fragments that fall upon their surface, or get frozen into their mass. They continue to bear them onward to the spot

where they melt away, when they of course deposit them, making heaps of blocks called *moraines*. Where the end of a glacier dips into the sea, many of these blocks are floated off upon and in the great masses of ice called icebergs, and when these melt, the fragments both large and small are of course dropped upon the bottom of the sea.

6. Having thus briefly glanced at the principal of the destructive effects of the mechanical action of water, let us now look to the reproductive effects of the same action.

It is obvious that all the materials thus removed by the wearing or eroding actions we have spoken of, are not thereby annihilated; when removed from one place they must be, ultimately, redeposited in another. The only change they can undergo is, that of a more complete subdivision of their parts, so that they are in smaller pieces than before; but those pieces, after being washed and carried about to a greater or less distance, will, at last, come to rest somewhere under the water. What will they ultimately form? It is sufficiently clear that if they are deposited from time to time in layer upon layer, or bed upon bed, so that a considerable thickness of such beds is accumulated, the lowest, being pressed by the superincumbent weight of the remainder, will be squeezed tightly together, and so compacted as eventually to cohere together into a more or less solid stone. This solidity is often aided by the mutual action of the different minerals composing the materials, or by the infiltration, through the mass, of dissolved minerals, such as lime, silica, iron, &c.

7. Now, all these substances, inasmuch as they are formed by materials mechanically removed from their orginal position, and brought by the mechanism of moving water into their present place, may be called "mechanically-formed rocks." Their principal varieties may be enumerated as follows:—

1st. *Siliceous or arenaceous rocks.*—Conglomerate or pudding-stone, breccia (in which the fragments are angular instead of rounded), sandstone, gritstone, gravel, and sand.

2nd. *Aluminous or argillaceous rocks.*—Clay, mud, clunch, marl, shale, clay-slate.

8. All the rocks thus formed by the action of water, either chemically or mechanically, may be properly called *aqueous rocks.* They are also called *stratified rocks,* because the materials of which they are composed have always been more or less regularly "strewed" over the bottom of the water, so as to form regular layers, beds, or strata.

9. It is easy to see that, in the course of a long series of ages, there may be, according to local circumstances, deposited at the bottom of any sea—either, 1st, a series of beds of any one of these kinds of material forming a great thickness; or, 2ndly, an equally thick series of alternations of two, three, or more kinds, in any imaginable variety of proportions. We may, accordingly, have beds of limestone, sandstone, and clay, or shale "interstratified" one with the other in all possible ways.

10. Moreover, it is quite possible that two or more sets of circumstances, such as currents of water from two or three different directions, one bringing sand, another mud, and a third, perhaps, water containing carbonate of lime in solution, may so combine that the resulting deposition may be a mixture of any two or of all three. Such combinations would be called clayey sandstone, sandy shale or clay, or limy clay or sandstone; or, if we use the Latin words, argillo-arenaceous, or arenaceo-argillaceous, or calcareo-argillaceous, or arenaceous rocks.

LESSON III.

STRATIFIED ROCKS.

"God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so."

1. Let us now examine some particular examples of stratified rocks, by the aid of the illustrations.

In fig. 1, of Donnybrook Quarry, near Dublin, we have a sketch carefully taken of one side of a limestone quarry.

Its first and most obvious characteristic is, that of stratification. Its parts are layers, or strata, or beds;

the upper and under surfaces of which are mostly parallel, and which are regularly arranged one upon

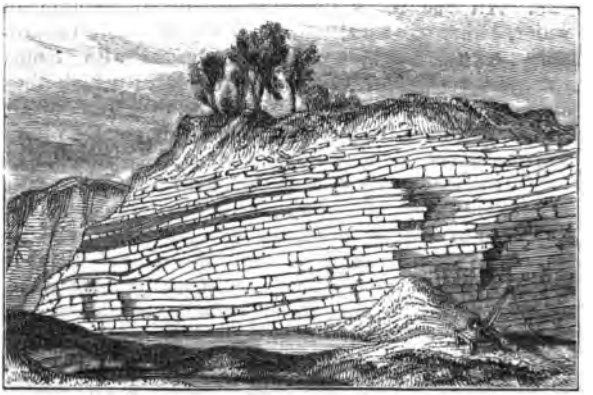


Fig. 1.—DONNYBROOK QUARRY, NEAR DUBLIN.

another. These regular layers are occasionally broken by short perpendicular lines, which are called joints.

2. The first idea we derive from such an example as this, is that of succession. These beds were not formed at once or in a hurried manner, but gradually and in a regular order of succession one after another, the lowest first, and then the next, and the next, and so on to the top. The next idea we get is, that this "succession" was not continuous but interrupted. We learn this from the very fact of the beds being numerous. Had the deposition of matter been continuous, the result would have been one solid bed from bottom to top. As it was, we see that there was, first, a continuous deposition forming the lowest bed, and then an interval or pause; during which interval, this lowest bed acquired more or less of coherence and consolidation before the next bed was deposited upon it. We see, then, that the whole set of beds was formed by a succession of small continuous depositions and interruptions or pauses, during which pauses nothing was deposited.

3. This is proved to us also by the minor irregu-

larities which we see in the beds. If we look in the figure, just about the centre of the small pool of water at the third bed from the bottom, we shall see that it is thick in the middle, and thins out in each direction till it ends. On one side of it, the bed above similarly comes to an end against it, each of them fitting, as it were, into the other: but the bed above those two is continuous over both of them, and also over the bed on which they rest, as may be seen on the side of the pile of rubbish that lies against this face of the quarry. Now this shows us that although, in one part of the quarry, this upper bed rests immediately on the lower, there was yet an interval between the formation of the two, and an interval sufficiently long to allow of the formation of two other beds of less extent, but equal in thickness with themselves at another part.

4. Similar facts are told us in other parts of this same face of the quarry. If, for instance, we look at the top of the heap of rubbish, before spoken of, and take the second bed above that, we see that it stretches throughout this part of the quarry, and for an indefinite distance beyond. There was, therefore, a deposition of materials sufficient to form it, over all that space, and a much wider one, perhaps, over miles of ground around it. Of the four or five beds immediately above it, however, we see that either from defect of material, or some other cause, none of them extended much further to the left, but all ended one after another in that direction in a gentle slope or bank. This is partially compensated for, in the beds immediately above them, which thicken over this depression, as we can easily understand would be the case with a depression or hollow at the bottom of any water in which sediment was being deposited, the slightest motion in the water having a tendency to sweep it into this depression where it would be caught and accumulated. Just above this spot, at the edge of the little cliff of the quarry, some beds of shale come in interstratified with the limestone. These are represented in the figure by the closer and darker lines. These beds are, as it were, dovetailed

into the limestone, each bed of shale getting thinner as it advances into the limestone and *vice versâ*.

5. Now this change teaches us another fact, namely, that the sea in which the limestone was being formed, was subject at intervals to have swept down into it, from one direction, black mud which, as it sank to the bottom, would of course be thicker on the side it came from, and gradually fine off in the opposite direction. This incursion of black mud might either be the result of some flood in a river in the adjacent land, some local and temporary change in a current, or some other of the many chances and changes which must happen in the course of ages, in every part and portion of the earth's surface.

6. All these phenomena tend to impress upon us the idea of a slow, and interrupted, and changeful succession of events, of which we have in this quarry the imperfect history and record. What we have here detailed is not even nearly so perfect a history as might have been gleaned from an examination of the quarry itself, and there is one branch of the subject on which we have not yet touched. It so happens that this particular quarry does not greatly abound in fossils; but there are abundance of other quarries in the same formation which are full of them. In some, indeed, it would not be possible to put even the tip of the finger on a piece of the stone without touching upon some fragment or relic of a once-animated existence. The examination of these fossils would teach us much. We should find various kinds of sea-shells, of corals, of crustacea, and of animals more or less nearly allied to star-fishes and sea-urchins. We should in some cases find colonies of animals that lived at the bottom of the sea, rejoicing in the clear water that was necessary to their existence, till after the lapse of years they had died either in consequence of the depositions of earthy matter, or had perished from other causes, and had their fragments included in it. In other cases we should find single valves of shells, water-worn, with their insides partly encrusted by small adhering corals or the cases of sea-worms;

showing, that the shell-fish itself had lived till it grew old, and had died, and that then its empty shell had been drifted about the sea-bottom, long enough for other animals to fix on it as a place of residence for their young, to deposit their ova on it, and for these germs to grow, and live, and cover it with their stony envelope before the shell was enclosed in the material in which we now find it.

7. Let us now turn to fig. 2. This is a sea-cliff on the shore of Waterford Harbour, near a little place called Ballyhack. The upper part is composed of thick-bedded

Fig. 2.—BALLYHACK, WATERFORD HARBOUR.

sandstone, interstratified with beds of shaly marl, the beds being nearly horizontal; the lower part is of highly-inclined beds of slate, as may be seen in the lower right-hand corner of the drawing. In a gap in the sandstone cliff is an artificial wall, with an arch in it, supporting a road, from which two figures are looking down.

This is a very instructive spot for a young geologist to examine, and the illustration will help us to describe it.

8. The slate rocks, which are the lowest, and which may be seen running all along shore at the foot of the cliff, are of a dark-blue colour, the sandstones and shales above are of a dull red. At the junction of the two,

where the sandstone rests on the upturned edges of the slate rock, it is found to be full of irregular fragments and pieces of slate. Now, it must be recollected that this slate is *clay slate*, and in the chapter on "Minerals and Rocks, and their Uses," it is shown that clay slate is an *altered* rock; that it was once clay deposited at the bottom of the sea, that it was afterwards hardened into stone, and then "cleaved" into slate by some wide-spread action, with the exact nature of which we are not accurately acquainted. In this case we see that it also has been "upheaved" and "denuded." The beds of clay must, when first deposited, have been horizontal; they have since then been tilted up and set on edge. They did not either all come abruptly to an end, as they do now, but spread for an indefinite and probably very wide distance beyond their present terminations. They have, therefore, had their former extensions denuded or washed away by the long-continued action of moving water brought to bear on their broken and tilted edges. This must have been a very long-continued action, because it can be shown, both here and elsewhere, that beds of hard rock, many thousand feet in thickness, have been thus removed. At length, however, there came a time when this destructive action was arrested. The last broken fragments and pieces became buried in sand, which was now brought into the water and thrown down upon them, in consequence of some great changes in the conditions of the district; and this bed of sand, containing shingle (called a breccia or conglomerate), was itself covered up by other beds of sand—forming sandstone, and beds of mud and clay—forming marl or shale. These have remained ever since undisturbed, except that they have been lifted out of the water in which they were deposited, into dry land; and that during that process large parts of them have themselves been worn away and removed, leaving the present cliffs, at the foot of which the slates have again been uncovered, and, together with the sandstones, are again subject to the wearing action of the breakers.

9. Fig. 3 is taken from the neighbouring coast of Wexford, at Carnivan Head, showing similar beds of

red sandstone interstratified with red marl, reposing on similar beds of upturned blue slate. It is meant, how-

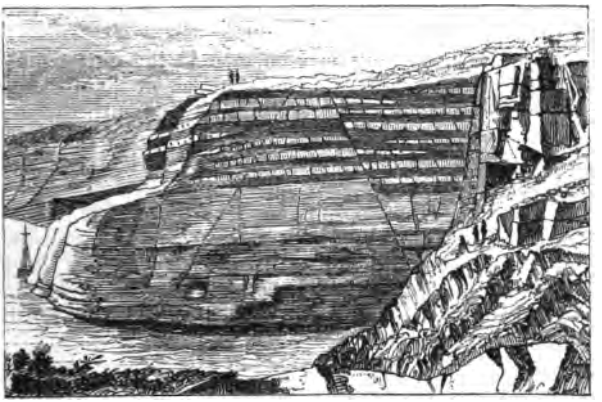


Fig. 3.—CARNIVAN HEAD, WEXFORD.

ever, to illustrate another geological phenomenon, that which geologists call a *fault.*

In the little headland which juts out into the sea, and on which two figures are standing, the upper part of the cliff is composed of red shaly marl, interstratified with thin sandstones, several of which thin out, and end in the way that was described in the Donnybrook Quarry. The lower part of this cliff is composed of very thick-bedded red sandstone, with no shale-beds, and with no blue slate exposed under it, though it probably would be found at a little depth under the surface of the sea. In the other part of the cliff, however, the blue slate, with its highly-inclined beds, forms all the part below that where the three figures may be seen, while above are thick beds of red sandstone forming the summit instead of the base of the cliff. At the angle of the two cliffs these thick-bedded sandstones are seen to come directly against the shales with the thin-bedded sandstones, both being horizontal and on the same level. They are separated by a nearly vertical crack or fissure, which is called a "fault." The beds on the outer side of this have been dropped down, or el-

those on the near side of it have been lifted up to such an amount, as to cause this displacement. This amount, when stated in feet or yards, is called the "throw" or "heave" of the fault.

Another little fault may be seen in the cliff facing the spectator, where an inclined crack or fissure displaces the beds slightly, producing a "downthrow" on the side *under which the fault inclines*.

10. In fig. 4, which is taken from the shore of Waterford Harbour, at a place called Booley Bay, we have an example of what geologists call "contortions." Here the strata have not been cracked directly through by fissures or faults, but they have been so bent and twisted by the action of the elevating and disturbing forces, as to have produced the result depicted in the figure.

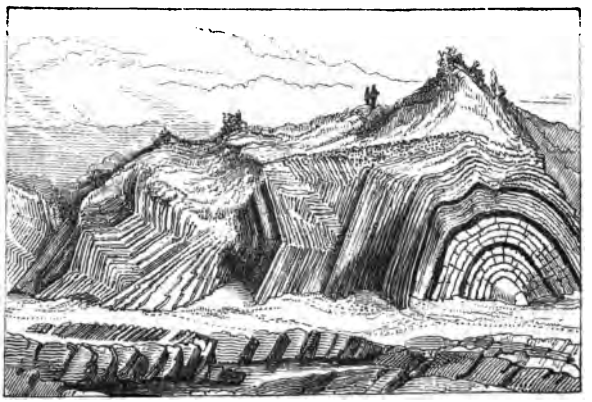


Fig. 4.—BOOLEY BAY, WATERFORD HARBOUR.

All the beds are composed of hard gritstone and slate rock; but in one part they are seen to be bent into arches as regular as any mason-work, and in another to have been crumpled up in such a fashion that one part has evidently been made to slide over the other, producing regular puckerings.

We must guard ourselves against supposing that such an effect as this was at all likely to have been produced,

when these beds were at or near the surface of the ground. In all probability it took place when they were buried deeply, probably many thousand feet under other similar strata; for they can be shown to have been certainly so buried once, and we can more easily understand this effect to have been the result of enormous internal force, overcoming immense superincumbent pressure, than of a force acting near the surface without much to resist it.

11. The next cut, fig. 5, is introduced in order to show both the method of accumulation of some rocks not yet spoken of, and to put us on our guard against always taking for granted, that highly-inclined beds have been upheaved by the forces just alluded to.

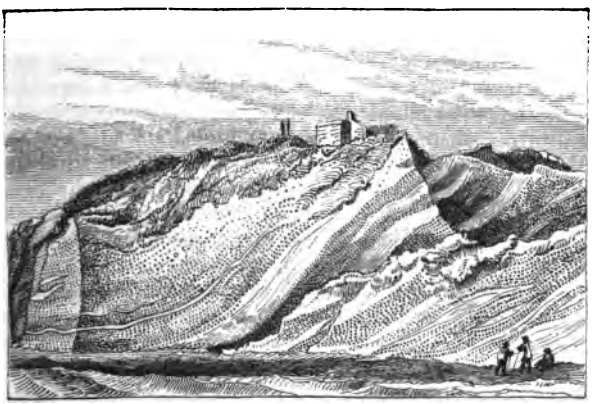


Fig. 5.—KILLINEY BAY, DUBLIN.

It is a sketch of a cliff on the shore of Killiney Bay near Dublin. The "rocks" here are loose incoherent sands and gravels and soft clays. These materials are very irregularly interstratified, the beds of sand and clay thickening or thinning rapidly, or often ending and setting in again. The gravels vary in coarseness, from the smallest pebbles to blocks the size of a man's head, and occasionally there is a boulder of granite some feet in diameter derived from the immediately adjacent hills. Many of the pebbles, however, and in

some beds the whole of them, are fragments of limestone, which must have been brought a distance of some miles at least, and some of those on the beach are chalk flints washed from the north of Ireland. In some places the stratification and the sorting of the materials, according to their several degrees of fineness, is pretty regularly carried out, the beds being for the most part horizontal; but in other parts the layers are suddenly inclined, curving upwards at an angle of 40° with the horizon over spaces of more than 100 yards in length, and through cliffs 50 or 60 feet in height. One such spot has been selected for the illustration. It is well marked by a thick bed of very fine sand, which is left white in the centre of the drawing.

This irregularity in the size and assortment of the materials, and the varied angle at which they have been originally deposited, is a sure proof that the deposit was accumulated in a comparatively shallow sea, where the currents were numerous and strong, and frequently shifting, and where the materials were from some cause very abundantly supplied. Banks of sand and pebbles having steep slopes were thus often formed, and the subsequent depositions were thrown down on the sides of these banks and conformed to their outline. Somewhat of the same effect, though to a slighter extent, may often be seen in all sandstones; it is then known to geologists by the term of "false bedding," or "oblique lamination."

12. Such are a few of the principal phenomena exhibited in the structure of the stratified or aqueous rocks. They teach us that all such rocks have been deposited under water, some very slowly, some more rapidly, at various intervals throughout a long succession of ages, and under a great variety of circumstances and conditions. They also show us that at different periods after their deposition, they have been subject to actions involving great disturbance, causing great elevations and depressions, great bending and breaking, and also great destruction and wearing away of the masses that had been thus deposited, and thus affected by disturbing agencies. We may learn too from what

has gone before, that there is not a pebble or a stone, or even a single grain of sand, or a particle of mud, that has not at one time or other formed part of a solid and extensive mass of rock.

LESSON IV.

IGNEOUS ROCKS.

"And set on fire the foundations of the mountains."

1. At the beginning of this chapter we entered slightly on the subject of igneous rocks, we must now briefly recur to the subject for the sake of showing that there are some not yet described, which, though igneous, are not, strictly speaking, volcanic.

We spoke there of lava and ashes being interstratified with one another, and of lava streams being porous and cindery above, while they are solid and compact below. The porosity and cindery aspect is the result of the easy escape of the pent-up gases from the parts near the surface, the gases blowing bubbles, as it were, *in the melted stone*. Pumice, we may look upon as *the froth or scum* of lava thus formed, just as much as the frothy head of a pot of porter is produced by the escape of the carbonic acid gas from the liquid. In the deep-seated parts of a lava stream, —those which have cooled slowly under the pressure of the superincumbent mass—all is heavy, solid stone, very often having a columnar structure, such as that described as belonging to basalt in a former chapter.

2. This, alone, would be sufficient to show us that basalt itself is probably an igneous rock, and this is proved to be the case in the following way:— Where a mass of basalt comes in contact with other rocks, such as clay, sandstone, chalk or coal, it alters the rocks it touches, just in the way in which great heat would alter them. Clay is hardened into jasper, sandstone into quartz rock, chalk into crystalline marble, and coal into a substance resembling coke. Moreover, wherever there is a large development of basalt, as in the celebrated district of the Giant's Causeway in County Antrim, there are almost always found one or two or more ranges of columns one above

another, interstratified with beds of volcanic sand or ashes.

Fig. 6 is a sketch of a spot called the Giant's Chimney, near the Giant's Causeway, where there are four ranges of columns interstratified with three beds of what is there called ochre, but which is nothing else than volcanic ash. These beds of ochre are of a bright yellowish-red, and are easily perceptible in the cliffs; they are left white in the sketch of the far headland.

Fig. 6.—GIANT'S CAUSEWAY, ANTRIM.

3. Basalt, with its kindred rock greenstone, often sends great wall-like masses called dykes; and also great and small veins into the cracks, fissures, and crevices of the rocks it comes in contact with. These intrusive rocks must evidently have been forced into the cracks and crevices, or between the joints of the limestone beds, while the "trap" was in a liquid or molten state.

4. Granite, syenite, and other similar rocks, send similar intrusive masses into the rocks, with which they come in contact, which alone proves them to have a similar igneous origin with basalt and greenstone. They, moreover, produce exactly the same kind and even a still greater amount of alteration on the rocks near them, altering shales and sandstones into mica-schist, and gneiss.

5. Another character, which is common to the granites

and the greenstones, and more or less to all igneous rocks, is that of crystallization; the minerals composing them being confusedly crystallized together. This crystallization shows the rock to have been once *fluid*. When these minerals are such as can be made fluid by water, like carbonate or sulphate of lime, or common salt, the rock itself may have been formed from such an aqueous solution. But where these minerals are such as are rarely or not at all soluble in water, such as feldspar, hornblende, mica, and quartz, while they are, either separately or combined, fusible by heat, it is obvious that an igneous origin is the one we must assign to them.

6. Another character common to the igneous rocks, and distinguishing them at once from the aqueous, is their want of stratification. It is true that great beds of them sometimes occur of regular thickness over pretty large spaces, and regularly interstratified with other rocks, but these beds have no internal marks of stratification within themselves. They are not *subdivided* into beds or laminæ, showing a gradual and successive deposition of layer upon layer to have produced the whole mass: on the contrary, the whole bed has evidently been poured forth at once, and any subdivision into parts has been a subsequent and superinduced arrangement.

This rearrangement is either the spheroidal one, giving a globular structure to the mass, that is, a tendency to form an assemblage of balls; or the prismatic one, causing the mass to split into long prisms or cylinders; or else what might be called the cuboidal one, giving a tendency to divide more or less perfectly into solid squares or cubical blocks.

7. These latter divisional planes are called "joints;" they are common to all rocks, igneous and aqueous, seeming to be the result of the consolidation of the masses, in passing from a soft or fluid condition into a solid one. They are, however, more perfectly carried out in igneous rocks, and of these most of all, perhaps, in granite. In this rock the joints are often so regular, at such equal distances, and different sets are so parallel

to each other, that one set might very often be mistaken for stratification, if further examination did not as frequently disclose another set, as regular but running in an entirely opposite direction.

Fig. 7 is a sketch in the large granite quarries at Killiney near Dublin, from which the stone was extracted, for the construction of Kingstown Harbour.

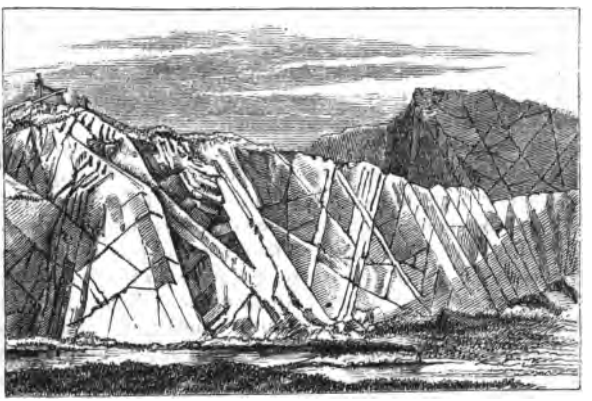


Fig. 7.—KILLINEY QUARRY, DUBLIN.

It exhibits the jointed structure of granite in great perfection, and as may be seen, one part of this, if looked at alone, might be mistaken for a regularly-bedded rock, if the supposition were not contradicted by the examination of the other part.

8. We have now briefly described the origin and method of formation of all the principal kinds of rock, stone or earthy matter, anywhere to be found upon the surface of the globe. It may next be asked how deep we suppose these materials to extend into the earth, and what is below or inside of them?

Depth of Rocks.—To the first question we can reply, that the rocks now described are known to extend much deeper below the surface than might at first be supposed. The direct excavations made into the earth are quite insignificant, the deepest of

them does not go more than five or six hundred yards below the level of the sea. We can, however, by examining the rocks as they successively come to the surface over a considerable part of the globe, reason back, more or less accurately, to what must be the structure of its crust to a depth, in some places, of several miles. We have already seen that in some places rocks originally deposited in a horizontal position at the bottom of the sea, have been heaved and tilted up, till they have been raised into a highly-inclined position, and lifted far above the level of its surface.

Most ranges of mountains which are not the mere edges of table-lands, but form ridges sloping steeply on each side, have been produced by the action of forces of disturbance along a certain crack or line on the earth's surface. The effect has been that along this line or narrow band, the lower rocks, and in many instances, the very lowest rocks we know, have been brought up to the surface, and the upper ones repose on the flanks of the mountains in regular order of succession, receding from the hills further and further, according to their place in the series.

9. Fig. 8 is a rough, diagramatic section to illus-

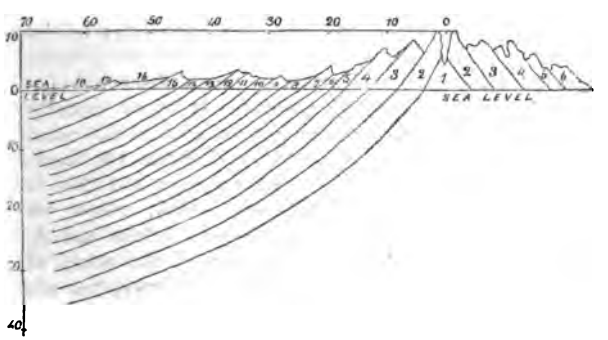


Fig. 8.

rate this. It is not intended for a representation of the

structure of any particular region, but merely to aid in the description of the facts.

Suppose we have 18 sets of beds, or formations as they are called, all perfectly regular in thickness, and lying in regular order one upon another, and that a mountain range, the top of which is ten thousand feet high, is produced at one part where these beds are so tilted up as that the lowest, No. 1, is exposed to view in the depth of some of its ravines, while the edges of Nos. 2, 3, 4, &c., are seen at the surface as we traverse the country from the hills to the lower grounds until we finally reach No. 18, forming a gentle plain sloping to the sea. The scale at the top and side of the diagram gives spaces intended to represent each ten thousand feet, from which it appears that when we arrive at the sea we have traversed a horizontal distance of 70,000 feet, or rather more than thirteen miles, and that then the upper part of formation No. 1, instead of being far above the level of the sea, as it is in the heart of the mountains, must be rather more than 35,000 feet (about six and a half miles) below it, with all the other formations lying regularly upon it up to the surface. Such exact regularity as is drawn in the diagram does not often occur in nature, but it is more or less nearly attained in some regions, so that by calculating on the principle here described, we arrive at a knowledge of the internal structure of the crust of the earth to a far greater depth than we could ever attain by direct observation.

10. Interior of the Earth.—It most usually happens that granite or other igneous rock is intruded into the heart of the mountains, and forms the basis on which the lower aqueous rock reposes; but this is not always or necessarily the case. Still, when we come to answer the second question lately asked, namely, what lies next below that part of the crust of the globe that we have been able to observe, we are reduced to the supposition that it must be granite or some similar rock. If we could descend still further into the interior of the globe it is probable, although it is not certain, that we should find it a mass of matter in a molten state, fluid from intense heat. We arrive at

this conclusion partly because of the immense masses of molten rock that have come from the interior to the surface over all parts of the globe, and are still being poured out over so many parts of it, and partly because the quantity and mass of these igneous rocks increase as we reach the lowest or what have once been the deepest-seated rocks. Moreover, actual observation on the temperature of mines shows us that the earth becomes hotter the lower we descend, and we have at present no reason to suppose that there is any limit to this increase of temperature if we were able to follow it. The amount of increase at present observed is 1° of Fahrenheit's thermometer for every 50 or 60 feet of descent after the first 100. If this should be regularly continued lower down we should get the temperature of boiling water at a depth of 9000 feet in Great Britain. If still further carried out we should reach, at a comparatively slight distance, a temperature sufficient to fuse the most refractory rocks, perhaps even pure silica itself. This great internal heat, however, is still conjectural, and there are some considerations which make against its existence.

11. SUMMARY.—We may sum up the results arrived at in this chapter in the following terms:—All rocks, stones, and earthy matter whatsoever have been subjected to the action either of fire or water, or of both.

It is probable indeed that all earthy matter may have once been part of a molten mass of rock. However that may be, it is certain that very large parts of the crust of the globe are simply the cooled portions of once molten rock. These are called *igneous* or unstratified rocks. All other earthy materials, whether soft mud or incoherent sand, or hard rock, are either the waste of such igneous rocks produced by the wear and tear of moving water upon them, and used over and over again in many successive combinations, or they are mineral matter that has been dissolved in water, and redeposited from it. These are called *aqueous* or stratified rocks.

When aqueous rocks have been so acted upon by subsequent heat as that their structure has become

altered, more hard, more crystalline, and more nearly resembling igneous rocks than they once were, such rocks are called *metamorphic* or transformed rocks.

We shall have to show in a subsequent chapter of this work that the aqueous or stratified rocks form a great regular series capable of being divided, arranged, and classified first into three great parts, called primary, secondary, and tertiary, and that these can then be subdivided into smaller portions just as a history is divided into volumes, books, chapters, and paragraphs. We shall see, also, how, from the study of this great series, some part at least of the history of the formation of the crust of the globe may be rescued from that dark oblivion of past ages, into which no ray of light can be thrown from any other science, or from any other source of human knowledge and intelligence.

J. Beete Jukes.

ADDRESS TO NATURE.

O Nature! all-sufficient! over all!
Enrich me with the knowledge of thy works!
Snatch me to heaven: thy rolling wonders there,
World beyond world, in infinite extent,
Profusely scatter'd o'er the blue immense,
Show me; their motions, periods, and their laws,
Give me to scan. Through the disclosing deep
Light my blind way: the mineral strata there;
Thrust, blooming, thence the vegetable world;
O'er that the rising system, more complex,
Of animals; and, higher still, the mind,
The varied scene of quick-compounded thought,
And where the mixing passions endless shift;
These ever open to my ravish'd eye;
A search, the flight of time can ne'er exhaust!
But if to that unequal; if the blood,
In sluggish streams about my heart, forbid
That best ambition,—under closing shades,
Inglorious, lay me by the lowly brook,
And whisper to my dreams. From thee begin,
Dwell all on thee, with thee conclude my song,
And let me never,—never stray from thee.

Thomson.

Vegetable Physiology.

BY EDWIN LANKESTER.

LESSON I.

THE FUNCTIONS THAT PLANTS PERFORM.

"The trees of the Lord are full of sap; the cedars of Lebanon which He hath planted."

1. The organs of which plants are composed are during the life of the plant in a state of constant activity. Each of the cells or vessels, of which these organs are formed, is in a state of perpetual change. The changes which thus go on in the cells produce changes in the condition of the organs, which are called the functions of the organ, and these collective actions are called the functions of the plant. A plant or animal in which these functions are performed is said to be alive, and the actions which attend them are called the life of the being.

2. The life of organic beings is attended with two very obvious results. First, the production of a series of actions, which can be traced to the influence of laws, which are known to act upon material bodies; and second, the assumption of a particular form or shape by a living being, which is determined by no agency with which we are acquainted. The first set of phenomena can be made the subject of experiment, and compared with the facts which affect matter when not in the form of plants and animals; whilst the second set of phenomena present us with ultimate facts, for the causes of which we must look to the immediate agency of the Divine Will. We can understand something of the nature of those changes by which carbonic acid gas and water are converted into the tissues and organs which compose an oak-tree, but we have no cause but the will of the Creator to assign for the peculiar form which the leaves, branches, stems, and other parts of the oak-tree constantly assume.

3. The various phenomena which characterise the life of plants are produced under the influence of those forces in nature which, to a greater or less extent, influence all forms of matter, whether it exists as a granite

mountain, a flowing river, or a gaseous atmosphere. The matter of which plants are formed obeys the same laws as that which constitutes the mineral kingdom. A living plant thrown into the air falls to the ground, with a rapidity, in proportion to its specific gravity and form, as great as that of a stone, or other mineral body. The water in the tissues of a plant is obedient to the same laws as that which composes the rolling waves of the ocean.

4. One of the most universal properties of matter is its *attractive force*—the power by which one particle of matter always draws or attracts another. This power is seen in one of its grandest forms in the attraction of the planets by the sun in our solar system, but not only does the sun attract the planets, but these bodies attract each other. This attraction can be seen in action wherever material bodies have liberty to move. Two pieces of cork in a basin of water will at last find each other, and come to rest side by side. The pieces of a wrecked ship at sea will be attracted to each other on the surface of the ocean, and after a few hours will be found all floating together. Thus floating seaweeds attract each other; and the gulf-weed of the Atlantic Ocean is found amassed together in moving fields, extending for several miles in every direction.

5. In the same manner as solid bodies attract each other, liquids are found to be attracted by solids. A piece of sugar in a spoon will attract water or tea poured into the spoon, and elevate it above the level of the liquid. A long piece of sponge, when dipped into water, will draw it up to its very extremity. A few threads of worsted hanging over the edge of a cup of water will empty it by the attraction of the worsted upon the water. Liquids will also attract each other; and two liquids separated by a solid substance, such as a piece of animal or vegetable membrane, will pass rapidly from one to the other, according to the attractive powers of the liquids for one another, and the liquids for the membrane. This process of the passage of liquids through membranes, has been named *osmosis*, and when the passage is directed into the side of a vessel or struc-

ture it is called *endosmosis*, and when to the outside, *exosmosis*.

6. Gases exert the same attractive power for each other as solid bodies and liquids. The researches of Professor Graham have shown that all gases mix with each other, in virtue of their attractive power: thus, carbonic acid gas, which is heavier than atmospheric air, passes readily into the atmosphere, and becomes intimately mixed with its other constituents. Hydrogen gas, though the lightest body in nature, will pass out against its gravity, from an inverted bottle with a long neck, and mix readily with the atmosphere. Gases are attracted also by solids and liquids. Charcoal, and the carbonaceous matter which forms the mould on the surface of the earth, readily absorb the gases of the atmosphere. The waters of the ocean, and of rivers, lakes, and ponds, are constantly absorbing the carbonic acid and oxygen gases of the atmosphere.

7. The application of the preceding facts to the explanation of the functions of plants, will be apparent when we consider that plants are made up of cells, which are composed of a solid material, having an attraction for liquids and gases. The substances from which plants derive their food are always presented to the plants in a liquid or gaseous form. The two sources from which plants derive their food are the soil and the atmosphere. In each case we find the plant presenting absorbing surfaces to enable it to take up its food. In the great majority of plants, the spongioles of the roots which are plunged in the soil are the great agents by which food is absorbed. But during damp weather, when rain falls, or the atmosphere is so filled with moisture that the process of exhalation cannot go on, there is no doubt that the whole epidermic surface of the plant is capable of absorbing food from the atmosphere.

8. We thus find that this physical law of attraction, lies at the very foundation of the life of plants. It is modified by a variety of causes; but the circumstances which modify the activity of this force, are all of them traceable to physical or chemical laws.

9. The next physical agent demanding attention, on account of its influence on the life of plants, is *heat*. The influence of heat is so obvious, that it needs but the most ordinary exercise of observation, to be convinced of its great power. In the temperate climates of the earth, such as our own, when the more direct rays of the sun are withdrawn, the vegetation of the earth begins to fail; and when the sun is at its greatest distance, the waters are converted into ice, the ground is covered with snow, and scarcely a leaf is to be seen upon the trees to indicate that there is life in the vegetable kingdom. But though this withdrawal of heat has suspended the more active functions of plants, the cells yet retain their susceptibility to the action of heat, and the sun's return upon the ecliptic brings with it the additional heat that develops the latent properties of the cells; and as the spring advances, stems, leaves, flowers and seeds attest the influence of heat on the life of plants.

10. Nor are we dependent upon observation in the great field of nature for a knowledge of the influence of heat. In the management of plants, the gardener is constantly performing experiments which prove that heat is a source of life to plants. Many of the plants that would perish in the open garden are preserved by placing them in a greenhouse, in which the heat is only a few degrees higher than the external air. Whilst plants which would perish in the greenhouse are made to flourish as though they were exposed to a perpetual summer, by being placed in the hot-house.

11. The nature of some of the changes produced by heat upon plants is perfectly well understood. One of the most remarkable effects of heat is its property of changing the condition of matter from solid to liquid and from liquid to gas. When heat is withdrawn from the vapour of water, as in the case of the vapour in the atmosphere, the water is precipitated in the form of rain; if water is still further cooled, it becomes ice. The converse, is also true; by adding heat to ice it becomes water, and by adding it to water it becomes steam or vapour. This power which heat has of combining with

water and rendering it vapour, seems to be the great means by which its effect on plants is produced. When the first heating rays of the sun in spring exert their influence upon the buds and germs of plants, a portion of the water of their tissues is evaporated. This evaporation calls into exercise the absorbing powers of the tissue, which now takes up moisture from without. The first impulse is thus given. The evaporation continues; and as the new liquid rushes in to supply its place, it brings food from without, and the processes of nutrition and growth proceed rapidly in proportion to the heating power of the sun's rays. In climates where the direct rays of the sun are always heating the earth, and in hot-houses, there is no winter and no spring, but a perpetual reparation takes place as fast as the old tissues are worn out or die.

12. It must not, however, be supposed that all plants require the same amount of heat to carry on their functions. In this respect they present remarkable differences. Some plants perform the ordinary functions of their life during the prevalence of our winters, and retain their green leaves during severe cold; hence they are called *evergreens*. Alpine plants flourish at the limits of eternal ice, and prepare for their subsequent rapid development whilst hidden beneath a mantle of snow. The varied vegetation of the earth depends in a great measure on the relation of each particular species of plants to the temperature of the different parts of the earth's surface. As the traveller passes from tropical regions either north or south, new forms of plants meet his eye as the heat becomes less oppressive. From tropical forests and gardens, where palm-trees, and figs, and bananas, ripen their fruits all the year round, he passes to regions where the myrtles, laurels, and tree ferns abound in the forests, and sugar, cotton, tobacco, and maize are cultivated in the fields. As he passes north and south, the apple and the pear, the cherry and the plum, are found in the orchards, and oaks, elms, ashes, and hazel-nuts are found in the forests. He is now in a zone which would embrace the southern parts of the British Islands. Wheat is here cultivated, but not in so great perfection as in lower latitudes

Passing on farther to the north, a gloomy vegetation sets in, and forests of dark pines characterize the uncultivated parts, whilst barley, oats, rye, and buckwheat are the cultivated grains. Farther north, vegetation becomes limited to alpine saxifrages, dwarf birches, and a few mosses and grasses. In such a journey the variety decreases as the traveller leaves the tropical climates and passes to the arctic and subarctic ones.

13. A journey up a mountain-side is attended with the same results: for the rarefaction of the air produces the same results as the obliquity of the sun's rays; and mountain ranges in tropical climates exhibit the vegetation of the tropics at their base, and those of subtropical, warm, temperate, and arctic regions, as the traveller ascends to their summits; and when high enough, the mountain is capped with snow and ice, and represents the barren and lifeless regions of the arctic and subarctic poles.

14. A not less potent ruler of the destinies of the vegetable kingdom is *light*. If heat is a king, then light is a queen in its power over the illimitable subjects of the vegetable kingdom. In nature there is no separation of these twin forces, whose agency results in the life of both plants and animals. The sunbeam strikes the earth as a compound of heat and light, and although addressing different senses in man, these act upon the vegetable kingdom together. We can however separate their influences. Man can manufacture heat of much greater intensity than he can light, and can thus expose plants or other objects to its influence alone. It has been thus discovered what heat cannot do in the vegetable kingdom. When plants are placed in hot-houses without light, they grow feebly; they do not develop their leaves and flowers, their tissues become delicate, and the whole plant quickly dies. It is thus that the conclusion is arrived at, that light exercises a powerful influence on the life of plants.

15. The action of light on plants depends on its power of producing chemical change. It is well known that light possesses chemical power, as it is by this

agency that it is employed in the beautiful art of photography. If two plants alike exposed to water containing carbonic acid are placed, the one in the sun and the other in the shade, it will be found that the plant in the sun will give off bubbles of oxygen gas, whilst the other does not. This results from the fact that the light of the sun has enabled the cells of the plant to decompose the carbonic acid, to appropriate the carbon and set free the oxygen.

16. The difference of the action of the rays of light is so great, that plants in a hot-house, where the temperature is the same, will not produce their leaves, flowers, or fruits on the side where there is shade, whilst plants exposed to the action of the sun-light produce all these parts in perfection. This is often seen in so simple an arrangement as plants placed in a room in a Ward's case. The side of the case next the window will exhibit a most flourishing vegetation, whilst the plants away from the window will become lank and weak, and die. The most prolific vegetation of the world is that found in tropical forests, where the direct rays of the sun furnish a much larger amount of light than is supplied to the subtropical and other parts of the world. Many plants indigenous to tropical climates will not flourish in the hot-houses of England; many will not produce their flowers, and many more do not ripen their fruits. This must be from the absence of light, as we have at our command any degree of heat that plants could require.

17. The only other physical agent that has been supposed to exercise an influence on the functions of plants, is *electricity*. This force develops itself in the form of what is called free electricity, galvanism, and magnetism. Although it has been often asserted that these forces exert a considerable influence on the life of plants, it has been found, by carefully-conducted experiments, that their influence when applied to growing plants is absolutely imperceptible.

18. Although plants are not influenced during their growth by electricity from without, they nevertheless exhibit a considerable amount of this force when in a state of growth. If a growing plant is insulated an

placed in connection with a gold-leaf electrometer, it will be found that the leaves will be extensively separated from each other. Currents of galvanism have also been discovered by means of galvanometers attached to growing plants. Such phenomena are evidently attributable to the chemical changes going on within the plant.

19. In the same way as electricity is accidentally developed, so may the other forces, heat and light, of which we have spoken; during the germination and the flowering of some plants a considerable increase of temperature has been observed. This undoubtedly arises from the chemical changes going on in the tissues at these periods. Under certain circumstances, especially in tropical climates, some forms of plants belonging to the family of *Fungi* give out a phosphorescent light.

LESSON II.

GERMINATION AND NUTRITION.

"I made me gardens and orchards, and I planted trees in them of all kinds of fruit.

"I made me pools of water, to water therewith the wood that bringeth forth trees."

1. ALL the processes of the life of plants, are more or less affected by the agency of the forces we have spoken of in the last lesson; and in referring in detail to the functions of plants, there is constant occasion to refer to their operation. One of the earliest series of phenomena in the life of plants is that which is called *germination*. When the seed of a plant is kept in a perfectly dry place, and free from the influence of heat and moisture, the embryo, or young plant, retains its vitality, or power of growth, for many years. In some instances seeds are said to have germinated which had been buried for even thousands of years, and cases have been reported of seeds taken from the tombs with Egyptian mummies being planted and growing. In none of these cases, however, have those precautions been taken which render them free from the suspicion that error has crept in. Evidence of a satisfactory character, however, has been brought forward to show

that the seeds of plants will retain their vitality above a hundred years.

2. Where a seed is placed in a moist situation, with a temperature of 50° or 60°, it begins to swell up, and, in the course of a few days, the calyx will be perceptibly enlarged. The young root is projected from the little hole prepared in the seed for its egress; and at the same time the incipient stem (plumule) is ready to be pushed up into the air. During this process of growth oxygen gas is absorbed by the seed, and carbonic acid is given out. This absorption of the one gas and discharge of the other does not occur in the tissues of the young plant, but in the albumen which surrounds it in the seed. The carbonic acid supplies the young plant with the materials of its growth before the root has yet struck into the ground, or the plumule opened its green leaves in the air.

3. The young plant having taken root firmly in the ground the stem lengthens and ascends into the air, whilst the root descends into the soil. Gradually the leaves are developed from the stem and branches, and the functions which contribute to the growth and existence of the individual plant come into full play. The root is the active agent of absorption, and the stem carries the sap to the leaves, which, by their expansion, expose it to the action of the heat and light of the sun.

4. The liquid which is absorbed by the roots of the plant contains the elements of its nutrition. The plant obtains its food from the soil as naturally as the animal obtains it from the stomach. The food of plants consists of water, holding in solution carbonic acid gas, ammonia, and certain saline matters. Without water the other substances could not be introduced into the system of the plant. Water forms a large portion of the bulk of all plants, and is essential to the supply of the gaseous and saline matters. It is not necessary that water should be supplied to plants in a liquid condition. If we calculate the quantity of water given off by exhalation from a field of cabbages during their growth, it will be found that a much larger quantity is given off

by the plants than falls upon the earth on the same space in the same quantity of time. Hence it is a correct inference that plants are supplied with water from the atmosphere in a state of vapour. Plants not only take up water by their roots in a state of vapour, but, whenever the atmosphere is charged with moisture, so that exhalation from the surface of plants is prevented, absorption of moisture takes place.

5. If plants are burned by a slow fire they give off hydrogen, oxygen, and nitrogen gases, and the solid carbon is left which is called charcoal. It was at one time supposed that this carbon was derived from a substance forming the principal part of all mould, called humus. But experiment has shown that plants cannot take up the humus, and, if they could, it would be impossible to assume that all the carbon contained in plants was derived from humus. In many parts of the earth, where plants have flourished for a thousand years without the addition of fresh humus, they have yielded annually large quantities of carbon. Plants supply animals with carbon, and the carbon conveyed away in their tissues from different soils must also be accounted for. The valleys of Switzerland have annually supplied Europe with immense quantities of carbon in animal and vegetable food, but no new humus is ever supplied to the meadows of Switzerland. The Pampas of America present a more abundant vegetation at the present time than ever they did in the memory of man, and yet Europe is annually drawing from off these plains—in the form of the hides, horns, bones, and fat of the wild oxen and horses—enormous quantities of carbon.

6. Cases even more decided than these are seen where trees have been planted in sandy soils where not a particle of humus could be found. In the last century a district in France between the mouths of the Gironde and the Adour, where nothing but blown sand existed, was planted with fir-trees. A forest now stands where at one time all was barren; and a vegetable soil, several inches deep, has been formed above the sand. In the serts of Sahara oases occur which have been produced

in the same manner by trees springing up amidst the unalloyed sand.

7. It is very evident from these facts that the humus of the soil is not the source of the carbon found in plants. There is no other means of supply but the carbonic acid of the atmosphere. That plants flourish when supplied with carbonic acid and perish for the want of it has been found by direct experiment. It is by this function of the vegetable kingdom that the atmosphere is deprived of the carbonic acid which is poured into it from various sources, and which, if it were not for this action of the vegetable kingdom, would so increase as to render the atmosphere speedily unfit for the existence of animals.

8. The sources of carbonic acid in the atmosphere are several. The first which we need mention is the respiration of animals. At every act of inspiration an animal takes in oxygen into its lungs, which, mingling with the blood, at last unites with carbon, and forms carbonic acid. The carbonic acid passes from the blood into the lungs, and is expelled at every expiration. It is thus that large quantities of carbonic acid gas find their way into the atmosphere. A human being is said to convert daily eight ounces of carbon into carbonic acid. Reckoning that the animal kingdom consumes twice the quantity of carbon of man, we can calculate the daily quantity of carbonic acid thrown into the atmosphere from this source.

9. Other sources of carbonic acid gas are the processes of fermentation and decay. These processes, which are the natural results of the decomposition of animal and vegetable matter, throw daily large quantities of carbonic acid into the atmosphere. Man produces, also, by combustion, enormous quantities of carbonic acid. As the use of steam increases, as the family of man extends, so do all the processes multiply in which carbon is employed as a combustible material, and carbonic acid results.

10. Another source of carbonic acid, and one that is often overlooked, is volcanic action. Every spring that bubbles to the surface of the earth comes up charged with carbonic acid. The fumes of every volcanic fir-

consist principally of carbonic acid—hence their deadly effect upon all who are exposed to their influence. But that which is deadly to man and animals is life to plants; and in the tremblings of the earthquake, and the smoking of the volcano, we have but preparation for the growth and increased development of the vegetable kingdom. The carbonic acid of the volcano has its origin in the mineral kingdom, and is the source of an ever-increasing supply of carbon to the surface of the earth, by which not only is the vegetable kingdom increased, but man and all other creatures that live upon it.

11. In the use of carbonic acid as food by plants we see one of the great features of the mutual relationship that exists between plants and animals. The functions of animal life result in the destruction of the substances which they have taken up from the vegetable kingdom as food, and the formation of carbonic acid gas is the consequence. This gas is poisonous to animals, and accumulating in the atmosphere would destroy all animal life, were it not for the absorption of it by the tissues of plants. The increase of the vegetable kingdom seems to have no other limit than the supply of carbonic acid; and as this gas is increasingly thrown into the atmosphere, from combustion and volcanic action, the vegetable kingdom is proportionately increased. From this fact we learn that the value of manures does not depend so much on the carbonic acid they are capable of giving off as upon their containing other constituents necessary to the nutrition of plants. The atmosphere is the great source of the supply of carbonic acid gas and the medium of communication between the animal and vegetable kingdoms.

12. Nor is the giving off of carbonic acid and its absorption the only relation between plants and animals. In order to form the carbonic acid which they give out, animals must consume the oxygen of the atmosphere; and if the quantity withdrawn was not speedily supplied, the atmosphere would become unfit for animal life. The oxygen thus taken from the atmosphere by the animal is contained in the carbonic acid;

which is taken up by the plant, and one of the results of the digestion of carbonic acid by the plant, is the appropriation of its carbon, and the disengagement of the oxygen. Thus plants are doubly purifiers of the atmosphere—first by clearing it of the carbonic acid, and second by restoring its oxygen.

13. Another constituent of the food of plants is ammonia, which is composed of nitrogen and hydrogen gases. It is from ammonia that plants obtain the nitrogen which is found in their tissues. Nitrogen is an essential constituent of the substance which, under the names of nucleus, cytoblast, primordial, utricle, and endoplast, constitute the first-formed part of every cell. Ammonia is produced under the same circumstances as carbonic acid; and wherever animal and vegetable matters are decomposed or formed, it is given off. It is also found present in the gases given off during volcanic action. It is, therefore, found present in the atmosphere, and exists there in sufficient quantities to supply all the demands of the vegetable kingdom. Another source of nitrogen is nitric acid, which is also found in the atmosphere.

14. The saline substances which are found in plants —such as the salts of soda, potash, lime, magnesia, iron, and other substances—are taken up into the plant dissolved in water. Although these substances are found in plants in very small quantities, yet their presence in the soil or water in which plants grow, seems to be essential to their existence. It is from the fact of these substances being taken up by plants, that the soil at last becomes exhausted and unfit for the growth of those plants which require the substances of which it has been deprived. It explains the necessity under which the farmer lies to change his crops from year to year, and thus avoid the exhausting the soil by one particular crop. This is called the "rotation of crops." In order to meet the demand of plants for food of a particular mineral kind, the farmer is compelled to add to the soil substances which are called manures. We have an example of these manures in the guano which is brought from the islands of America and Africa

which is rich in the mineral elements required by plants. The superphosphate of lime, formed by pouring sulphuric acid on mineral and fossil phosphate of lime, is another example. We cannot always ascertain from the chemical analysis of the ashes of a plant, the form in which its necessary elements are best supplied; but sufficient is already known to lead to the hope that the food of plants will be one day supplied with so much accuracy that the same crops will be continuously produced in the same soil.

15. The raw food of plants, consisting of water holding in solution the substances named above, is absorbed by the roots of plants. The cells on the outside of the spongioles first take up the liquid, which is conveyed from cell to cell till it pervades every part of the plant. In countries where there is a cessation of the active functions of plants from the withdrawal of the light and heat of the sun, a season of activity comes on when the sun's rays are again more powerful. This occurs in the spring in this country, and at that time a current of liquid passes into the plant, and passing regularly up the stem to the leaves, is called the *ascent of the sap*. This upward current of the juices of the plant, continues as long as the leaves and branches continue to unfold, and present the sap in their cells to the action of the light and heat of the sun. As the sap passes upwards it nourishes the growing tissues in all directions, and in the leaf it is constantly parting with the water which has been taken up from the soil.

16. The process by which the leaves get rid of the water is called *exhalation*. It is one of the most essential processes in the life of the plant, and is mainly dependent upon the heat of the sun, causing the evaporation of the water of the sap. The more rapid the exhalation the greater is the demand made by the tissues of the plant for more liquid from the soil, and in proportion to the loss of water above will be its supply from below. It has been found by experiment, that plants give one grain of organic matter for every two hundred grains of water exhaled, and one grain of inorganic matter for every two thousand grains of water exhaled.

17. It has been supposed that the leaves are not only organs of exhalation, but that they elaborate the sap which is brought into them. The various secretions which are found in the roots, stem, bark, and branches, have been supposed to be formed in the leaves, and to have been carried down from these organs into the parts in which they are found. This has been called the *descent of the sap*. There are certain phenomena, which seem to favour this view; but that there is any constant transportation of secreted matters from the blade of the leaf back through the petiole into the stem, has never yet been proved.

18. One of the great arguments used in favour of a descent of the sap, is that trees when wounded present always a larger amount of secretion at the upper, than at the lower part of the wound, as though there was a tendency of the sap to force its way downward. This phenomenon can, however, be as easily explained on the supposition, that there is a general diffusion of the fluids of the plant, which necessarily exude in largest quantity from the most dependent part of the cut surface. If a branch of spurge is cut through, it will be found that, provided the quantity of matter above and below the wound is about the same, the milky juice flows out more or less rapidly from either cut surface, according as they are held down or up.

19. In the same manner it has been supposed that the wood of the tree is formed from ligneous matter sent down in the form of roots from the leaves. It is true, that after the great rush of sap has taken place, and the water evaporated from it by the leaves, that the fluid which is left has a tendency to gravitate towards the lower part of the plant, and that the tissues which are most abundantly supplied with this fluid, containing generally (in addition to the raw food of plants, of which we have spoken), sugar, dextrin and gum, will develop most rapidly. In this way the cells connecting the wood of the bark and stem with the leaves get nourished first, and an early appearance of vascular tissue in this point has led to the conclusion that the leaves send down the woody tissue. It is also true that in plants

with leaves, little or no wood would be found if the plant was deprived of its leaves; but this arises from the leaves being the agents of evaporation, and the supply of new matter from the soil is mainly dependent on the water exhaled from the leaves. For the same reason plants deprived of their leaves do not deposit secretions in their stem and roots.

20. That the cellulose which composes the walls of vegetable tissue is formed by the cell itself, and not in the leaf, is proved by a variety of facts. There is no difference in the nature of the woody tissue and the cellular tissue of plants, except in form; and what is true of the growth of one must be true of that of the other. We find cells of the hardest kind and very much elongated amongst plants without leaves, such as the *Cactaceæ* and many of the Cryptogamia which have no true leaves. In the bark of many trees, as the Cedar of Lebanon, the Oak, and especially the Beech, are often found nodules or knobs which are entirely surrounded by the cellular layers of the bark, and yet when cut into they present all the characteristics of wood (figs. 1 and 2).

Fig. 1.

Fig. 2.

The history of these knobs is curious. They were originally buds—adventitious buds in the bark of the tree; adverse circumstances prevent the elongation of their tissues, and their development into a branch with leaves, but they retain sufficient vital force to appropriate nutriment, and to increase from year to year with the periodical activity of the plant; hence

they present regular zones as in the stem of a tree (fig. 2). They are in fact branches which are not fully developed, and have very properly been called "abortive branches."

21. Another proof that wood is not sent down from the leaves, is the fact that when trees are felled in the spring of the year after the sap has begun to rise, it will be found that a layer of woody tissue is formed in that part of the trunk which is left in the ground, and this after all the leaves and the upper part of the tree have been removed. So also in ringing trees, although the largest quantity of the new wood is found at the upper part of the ring, yet there is always a considerable development of woody matter from the lower tissue, which ought not to be if the tissue of the wood is formed by the leaves.

22. In the greater number of plants that endure for more than a year, the age of the whole plant or of particular branches may be estimated by the number of yearly zones of wood presented by these parts. These zones, which around the pith are thin and of small size, frequently get thicker towards the circumference of the branch or stem; nevertheless a small portion of wood taken from the trunk of the tree becomes the index to the age of the whole tree by means of the number of zones it presents. Thus if an inch presents five zones, and the distance from the circumference to the centre is ten inches, which is calculated from the measure of the circumference, then we may conclude that the tree, is fifty years old. It is in this way that an enormous age has been assigned to some existing trees. A specimen of deciduous cypress growing at Chapultepec, in Mexico, is estimated to have stood upwards of six thousand years. Baobab trees in Africa have been estimated at upwards of five thousand years. The Wallace Oak at Ellerslie, near Paisley, is above seven hundred years old. The yew-trees at Fountains Abbey, in Yorkshire, afforded shelter to the monks, whilst the beautiful building now crumbling into ruins was being erected. Various other instances are recorded of the great ages to which trees have attained. It should, however, be remembered that

a tree is not an individual, but rather the debris—the remains of myriads of individuals. Each bud may be regarded as an individual; and the permanent trunk and branches are the result of the activity of individuals that annually perish to make way for another race, who in their turn contribute to the many-formed mausoleum of vegetable activity.

LESSON III.

MOVEMENTS IN PLANTS.

"I the Lord have brought down the high tree, have exalted the low tree, have dried up the green tree, and have made the dry tree to flourish."

1. These general phenomena of the growth and nutrition of plants, are attended with special actions in the cells and organs, which now demand our attention. The phenomena of the ascent of the sap, and the exhalation of water from the leaves, and the growth of wood, can only be well observed in perennial plants, which are called shrubs and trees. But many plants exist which consist only of simple cells, whilst the great bulk of flowerless plants possess no true stems, branches, nor leaves. Yet the simplest plants perform all the functions which have been observed in those which are most complicated. A simple cell of the red snow plant, or of any of the simpler forms of *Alyæ*, *absorbs* its food from without. Its *food* is water, carbonic acid, and ammonia. These compounds it digests or chemically changes; and movements are observed within which are analogous to those which are called the ascent of the sap, and constitute a kind of *circulation*. The prepared fluids, thus elaborated and moved, are devoted to the thickening and enlarging of the cell-walls, and thus the function of *assimilation* is effected. The parent cell-wall decays, and *death* ensues. But whilst death destroys the parent, a new crop of cells is generated in its interior, and a constant *reproduction* takes place.

2. When the cells of a plant are not united, the more intimate nature of the functions they perform can be observed. It is when cells of this kind are placed under the microscope that it is seen that the interior protoplasm, nucleus, or endoplast, which lies at the founda-

tion of all cells, is one of the most active and necessary parts of the structure of a plant. Not only are cells formed through the agency of this substance, but it is the source of all that power or force which constitutes the life of the plant. One of the most remarkable properties of this substance is its irritability or power of contracting and expanding, which, when it occurs in cells which are free, and only covered with a delicate membrane of cellulose, results in the active movement of such cells. It is this substance, which is transferred from the vegetable to the animal kingdom, and being arranged in the form of muscular and nervous tissues, give motion and sensibility to animals; so that we now find that not only is not motion a distinctive feature of the animal kingdom, but that the material of the motor organs of animals is derived from the vegetable kingdom.

3. Not only is the protoplasm in the interior of cells motile, but in a large number of cells, especially the reproductive spores of aquatic plants, it sends out minute projections from its surface, which are constantly in a state of motion. These minute hair-like bodies are called cilia, and where they occur are the active cause of motion, in both plants and animals. In plants they are chiefly observed either in those which are permanently unicellular, or in the spores of *Algæ* which reside in water. Many of the plants which possess these organs were formerly regarded as animals, on account of their great locomotive power. One of the most beautiful of these objects, which is frequently even now described as an infusorial animalcule, is the *Volvox globator*. This organism consists of a number of green spore-like bodies, each possessing two cilia, which are arranged in the form of a globe, the green bodies being held together by a beautiful network of tissue. When in the water, the cilia are constantly in action, and thus this sphere of emerald gems is kept in continual motion in the water in which it lives. Two families of the lower forms of *Algæ*, which were once regarded as animals—the Diatoms and Desmids, remarkable for their movements, although cilia have not been detected in them—are now generally referred to the vegetable kingdom.

4. Amongst the higher forms of plants, where cells are united and formed into organs, these movements are not so obvious, but this arises from the interior protoplasm being covered over with too thick a covering of cellulose to allow of their being developed; at the same time large numbers of plants exhibit movements in their leaves, flowers, and other organs. The leaves of plants are observed to unfold and shut up: many flowers open at one part of the day to close at another; whilst others, as the sunflower, move so as to present the interior of their flowers constantly to the direct light of the sun. So regular are many of the movements by which the petals of flowers are expanded and closed, that Linnæus constructed what he called a Floral Clock, by which the hours of the day might, at any time, be found by the opening or shutting of certain flowers. It is, however, in sensitive plants, as they are called, that we observe the greatest amount of this vegetable movement. In these plants, which belong to various genera in the order *Leguminosæ*, and more especially to the genius *Mimosa*, the leaflets which grow on each side of the central midrib fold up when they are touched. If they are touched at the top of the leaf, the uppermost of the leaflets first fold up, and these are succeeded by the lower ones; then the next leaves begin to fold up, from the base to the point; and last of all, the petiole will frequently and suddenly bow itself down, so that the whole plant is shut up. In tropical countries, where these plants grow, their sensibility is so great, that the wind passing over them, or the shaking of the ground with the foot, will cause the leaves to fold up. In Senegal, one of these plants bows itself down so remarkably when it is approached, that the native name for it is the 'How d'ye do.' Another of these plants, the *Desmidium gyrans* of botanists, is continually moving the leaflets of its leaves, which are ternate, and the leaflets are constantly varying their position in relation to one another; the two side leaflets alternately moving up and down, whilst the middle one moves more slowly, and directs its movements first to one side and then to the other.

5. The same kind of irritability is seen in Venus' Flytrap, the *Dionæa muscipula*. The margin of the leaves of this plant are furnished with a series of strong bristles, which, when the leaf is closed up, fit into each other. If a fly or other insect alight upon these teeth, the leaf instantly closes up, and makes the luckless fly a prisoner. It has been supposed that the plant has an object in catching these flies, and that they serve as a kind of manure by which it is nourished; but plausible as this theory is, there seems to be no proof of its truth.

6. The stamens of the Barberry afford another familiar instance of this irritability. If the stamens of this plant, when in full flower, be gently touched with the point of a pin or other sharp instrument at their base, they rise up and cause the anther to strike the stigma with a sharp blow. The ultimate end of this movement is evidently the scattering the pollen of the anther over the surface of the stigma. In a plant called *Stylidium*, the flower contains in it a central organ, which is bent over on one side of the flower, and when touched it sways over to the other side. Several instances are also recorded among Orchidaceous plants, in which different parts of the flower betray great irritability on being touched.

7. Another set of movements which occur in plants are those which are observed in the interior of their cells. These movements consist in general of a very regular motion of the contents of the cell, whether these consist of starch, oil-globules, chlorophyll, or other matters. In all cases they are only to be detected by the aid of the microscope. Although the observation of these movements was for a long time confined to a comparatively few plants, they have now been observed in almost all kinds of water-plants, and in the hairs of nearly every species of land-plant. This kind of circulation was first observed in the species of plants belonging to the family *Characeæ* (fig. 2, p. 62). These plants consist of a stem and branches, which are all composed of single large cells growing one on the top of the other. Some of these are covered with an external tegument of hard matter which needs

to be removed before the movements in their interior are seen. In others the movements are seen without any preparation.

8. Subsequently these movements were discovered in the cells of the Frog Bit (*Hydrocharis Morsey Ranæ*), and more recently in the long leaves of the *Vallisneria spiralis*. This plant is a native of the south of Europe, but since the discovery of its cell-circulation, it has been very constantly cultivated in England, and from the readiness with which it grows, it is well adopted for aërating small fresh-water aquavivaria. A more recent discovery of these movements has been made in the leaves of the new Water-weed (*Anacharis alsinastrum*), which is now so plentiful in our ponds, rivers, and canals, as to threaten the extirpation of every other water-plant. With care, this circulation may be seen in all kinds of water-plants, from the lowest *Algæ* up to the highest form of exogenous plants that grow in water.

Fig. 2.

9. This movement is not in all cases precisely the same. In Vallisneria and Anacharis the particles move slowly up one side of the cell and down the other. All the particles, whether of chlorophyll or other substance, seem to move at the same rate, and in a kind of stately manner, one never attempting to pass another. When one stops, all the rest stop behind it, till the first one, having got over the impediment, they again resume their solemn march. In the hairs of plants the particles moved are generally much more delicate, and

higher powers of the microscope are required to see them. The particles do not move directly up and down the sides of the cell, but frequently take an oblique course across the cell. In the cells of the fruit of the Snowberry (*Symphoricarpus racemosus*) the particles cross the cell in several directions. In those cases where the current appears to move in a particular groove, the line of direction varies; and if a drawing is made of the lines of direction of the current at one time, they will be found to differ very much if another drawing be made at the end of an hour or two. Various modifications in the direction of these currents have been observed in various plants.

10. These currents are affected by the age of the cells. In very young cells they are not observed at all. In aged cells they cease. They are seen to greatest perfection in those cells which are growing most rapidly, and form the great bulk of maturing leaves. External circumstances affect the movement; when exposed to cold it ceases, and also when exposed to a high temperature. It is therefore necessary, in observing this phenomenon, to take care that the heat is sufficient to bring the motion into action, and not great enough to arrest it. Another curious circumstance connected with this motion is its permanence in many instances. It is not only best exhibited in sections of the leaves of *Vallisneria*, but it continues to be visible for hours although the plant has been thus mutilated. It even continues for months after the leaf has been separated from the rest of the plant, and it has begun to exhibit the yellowness of decay.

11. The cause of these movements was at one time involved in much obscurity; and electricity, molecular affinity, and other forces, were called in to give an explanation. After the discovery of cilia on the surface of vegetable cells, it was supposed that a development of these organs in the interior of the cell would account for all the phenomena; and indeed there are not wanting those who believe they have been able to distinguish such organs in the lining membrane of the cell. Whether these are really cilia or not, there can be no doubt that t'

active cause of the movement is the lining protoplasm or endoplast of which we have spoken before, and which, in accordance with its inherent nature, seems constantly, when exposed to a certain temperature, to be in a state of movement. In *Anacharis* this protoplasm is observed to contract and expand. When it contracts, it gathers together all the cell contents to one end of the cell, but when it unfolds, it spreads itself around the sides of the cell, and the particles now set free begin to move up and down the sides of the cell, under the influence of perceptible vibrations or undulations of the protoplasm or lining membrane of the cell.

LESSON IV.

DECAY AND REPRODUCTION.

"For there is hope of a tree if it be cut down, that it will sprout again and that the tender branch thereof will not cease."

1. We have now spoken generally of the functions which are necessary to maintain the life of the individual plant: but all these processes end in death. The leaves, which while they are growing draw up so large a quantity of sap from the stem, and put in action the absorbing powers of the root, at last attain their full development. The material at first expended on their growth is now deposited in their interior; as the walls of their cells become thickened they absorb less fluid, and at last this process is arrested altogether. The chlorophyll, which had hitherto been green, now turns yellow, and at last red: the rich hues of an English autumnal scene are painted on the leaves of the varied vegetation, and if the autumnal winds do not sweep them away, they fall naturally to the ground. A little scar upon the branches of perennial plants mark the spot where the leaf was attached to its parent stem.

2. Even with the stems and branches, the time comes when they too must die. Some fall with the first frost in winter, and these are annuals; others continue for two years; whilst those which resist the cold and other influences for years at last die. The rain gets into some accidental crevice in the stem, and decomposition once 'tting in, the process of decay proceeds, till at last the

monarch of the forest bows his head to the storm, and lies prostrate on the ground. But whilst individual leaves perish, and whole plants die, provision is made for their renewal. When the leaves drop off a perennial plant, they leave in the corner of the little angle formed between their petiole and the branch of the tree, a bud which endures the winter's cold, and the following spring grows forth into a branch covered with leaves. And, even with the plants that perish altogether, we find, if we wait, that in dying they have shed around them upon the silent earth the germs of a new life. These germs are contained within the seed, the little central organ which is hid up in the leaves which have been changed into fruit, and which were ushered into existence through the agency of the flower.

3. Plants then are propagated in two ways—by buds and seeds. The buds, however, only propagate the individual plant, the seed produces a new individual. Buds produce plants precisely like the stocks from which they have been taken, but seeds produce a new individual, which frequently differs considerably in unimportant characters from its parent stock. This is well seen in what occurs in the cultivation of fruit-trees. Thus all the buds which were taken from the original ribstone-pippin apple-tree, in Ribstone Park, in Yorkshire, produce the same kind of apples; and all buds taken from these trees produce apples with the same flavour and characters as the first ribstone pippins in Ribstone Park. But if we now take a seed from a ribstone-pippin apple, and plant it in the ground, the tree that comes up will not yield ribstone-pippin apples, but a fruit with very different qualities indeed. The buds, then, must be regarded as an aggregation of cells which have the power of living independent of the parent tree. It is as though a man should cut off his thumb or finger and it should have the power of growing up into a man like himself. Although man does not possess this power, it is found in many of the lower animals, large numbers of which are produced by buds growing upon the parent in the same way as plants. Sometimes the bud drops off spontaneously, as is seen in certain lilies,

when they are called bulbilli, and produce a new plant in the same way as seeds. Even this is seen in animals, where a sort of egg instead of a bud is formed, and being separated from the parent animal, is developed at a subsequent period.

4. Although at one time it was supposed that only the higher forms of plants produce new individuals from seeds, it appears that probably in all cases a seed, or an organ homologous with it, is necessary to the continued production of new individuals belonging to every species of plant. The fundamental difference that was supposed to exist between a seed and a spore, was, that in the formation of a seed, it was necessary that two cells should unite, whilst in the spore only one was found necessary. It has, however, been found amongst many of the lowest plants, that two cells constantly unite for the purpose of forming the spore, and that all cells which produce new plants without this union of the two cells, may be regarded as buds. This can be well seen amongst the *Diatomaceæ* and *Desmidieæ*, which are plants which, instead of having a large number of cells held together in a definite form, have their cells floating about in the water. We may conceive of the nature of these plants, by supposing that an oak-tree had fallen into the water, and that instead of being held together in the usual form, the cells all separated without losing their powers of growth. In such a case there would be certain among these cells which would represent the two sets of cells which go to form a seed. These two sets of cells would go floating about in the water; but at last, just as they find one another in the complicated arrangements of the flower, they would meet each other amidst the other cells in the water. The consequence of the union in the one case, as in the other, would be the production of an individual capable of growing under the same conditions as its parent had done before it. A set of diatomaceous cells, then, floating in the water, differ from those which are found united in an oak-tree, not in the functions of growth, or the laws of their reproduction, but in their mode of union. Thus we may have as many cells in

the individual diatom as we have in the individual oak-tree, if we agree to regard as one *individual* all the cells which are the result of the growth of the spore or seed which is produced by two individual cells.

5. Nor is the above an imaginary case, as far as the union of the cells of the *Diatomaceæ*, *Desmidieæ*, and many of the other lower forms of *Algæ*, are concerned. Amongst those forms of *Confervæ*, which are known by the name of Zygnæmas, or Yoke-threads, it has long been known that the elongated filaments, as they lie beside each other, unite one to the other by means of

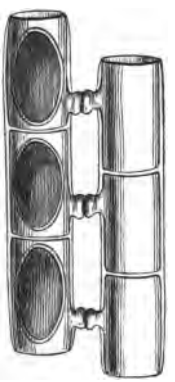


Fig. 3.

Fig. 4.

little tubular projections, and that through those tubular projections the contents of one cell is transferred to the other, which then produces a spore (fig. 3). The same process has been observed to take place in the cells of the *Diatomaceæ* and *Desmidieæ*: and as there could be no doubt that the Zygnæmas were true plants, this fact of the union of separate cells in the diatoms and desmids led to their being regarded as plants, and not animals.

6. The existence of two sets of cells, whose union is necessary to the production of the body from which the new plant is to spring, has now been observed in all the families of what are called Cryptogamic, as well as those which are called Phanerogamic plants. As we ascend, however, from the lowest *Algæ* to the highest plants, we find various arrangements of the tissues by which these two sets of cells are distinguished. In some of the *Algæ*, as the common Bladder-wrack (*Fucus vesiculosus*, fig. 4), the spores produce a mass of cells which assume the form of a membrane: on the surface of this there arise two distinct heaps of cells, in the midst of one of which there lie several cells, which represent the ovules on higher plants, and on the other elevation are a number of motile eel-like bodies which are called Antherozoids, and represent the pollen-cells of higher plants; the latter finding their way to the ovules, the spore or seed is produced from which the new plant springs.

7. In the Ferns, the spore-cases at the back of the leaves or fronds contain spores or cells, which, falling on the ground, begin to produce new cells: in this respect, they resemble buds. These cells form an expanded mass, having a green colour, and looking like a frond of Marchantia; hence this organ in ferns has been called the marchantia-like expansion. On examining the surface of this expansion, it will be found that it is composed of three different kinds of cells. First, the ordinary cells of the tissue; second, cells containing ovules, and which are called archegonia; and, thirdly, cells containing antherozoids, and called antheridia. The union of the contents of the two last cells produces the young plant, which grows up to be a fern. We meet with the same distinction of cells, with various arrangements for their accommodation and the effecting their union, on the Lichens, Mosses, *Fungi*, *Characeæ*, *Lycopodiaceæ*, and other families of cryptogamic plants.

8. Amongst phanerogamic plants the arrangements for the union of the two cells is more evident. In the

great majority of plants the flowers contain two sets of organs, the stamens and the pistils. Sometimes these organs are seated in different flowers, and even on different plants, as in the case of monœcious and dicœcious plants. In the pistil we have contained one or more cells, called ovules (fig. 5, *d*). It is in the centre of these ovules that the young plant is formed, which is called the embryo, and the ovule itself is converted into the seed. This, however, is only effected through the agency of the other set of cells. Surmounting the filament of the stamen is a little valve-case, or box (more frequently two), which contains a large number of minute cells, which vary in form in almost every different plant, and which are called pollen-cells. When the flower of the plant is fully expanded, the case of the anther containing the pollen-cells bursts, and the consequence is, that these small cells are immediately conveyed to the surface of the stigma (fig. 5, *c*), where they remain in large numbers exposed to the action of its moist surface (fig. 5, *a*). The means are very numerous by which the pollen-cells find their way to the stigma, especially in plants where the stamens and pistils are on separate flowers. In some cases certain jerking movements of the stamen transfer the

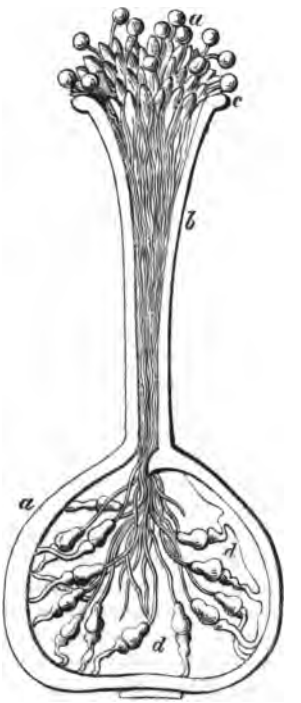


Fig. 5.

pollen-cells to the stigma. In other cases the anthers grow above the stigma, or the flowers droop and allow the pollen-cells to drop down upon the stigma. In monœcious and dicœcious plants, insects are at one time the means of distributing the pollen, and winds at another. Sad are the consequences when wind and rain combine at the period of the shedding of the pollen, in wheat and the other cereal grasses, to prevent the pollen from reaching its destination on the stigma.

9. A knowledge of the necessity of the union of the two sets of cells to produce seeds and fruit induces the gardener to seek artificially to introduce the pollen of the flower of one plant to the stigma of another. This is constantly done in the culture of cucumbers and melons. This is also the way by which the gardener secures new varieties of plants. By taking the pollen of one variety of plants belonging to the same species, and introducing it to the stigma of another variety, he secures seeds which will produce plants having qualities differing from those of either of the parents. This is one of the fertile sources of the endless varieties of the same species of flowers and fruits which are constantly being produced by the gardener. It is not often that the pollen of one species will fructify the ovules of another. Such occurrences do, however, take place, and the offspring of plants which are thus produced are called *hybrids*. Such hybrids do not often occur in nature, although it appears when different species of plants closely allied grow close to one another it sometimes happens. Such hybrids quickly revert to the characters possessed by either one or other of the parents.

10. When the pollen-cell falls on the pistil, the effect of the moisture of the stigma is to cause it to shoot out a projection, which is called the pollen-tube (fig. 5). This tube passes down the tube in the style of the pistil, and finds its way into the cavity or germen of the pistil. Here the ovules or seed-buds are arranged in various ways, but in such a manner that the pollen-tube may pass into the little hole called the micropyle, which is found at the point of every ovule. Soon after the in-

troduction of the pollen-tube, the innermost cell of the ovule, the embryo sac, begins to enlarge, and a number of new cells are formed in it, which ultimately become the embryo or young plant. There has been much difference of opinion on this point, for whilst one set of observers maintains that the pollen-tube only induces changes in the embryonal cells which are contained in the sac of embryo, another set of observers maintain that the pollen-tube doubles down the embryo sac, and itself becomes the young embryo.

11. From this period the ovule becomes the seed. The young embryo continues growing till it has attained a certain size, and the seed is fully matured. In all cases it is either surrounded by a quantity of additional matter, which is called the albumen, or the albumen is absent and the cotyledons or seed-leaves are very large. The former condition is seen in such seeds as the walnut, whilst the latter may be observed in the bean and pea. In either case the albumen or the cotyledons contain the nutrient matter which, by decomposition and softening under the influence of moisture and heat, are to start the young plant in the career of growth and organisation, which we have endeavoured to trace.

12. Here, then, we close our remarks on the functions of plants. We commenced with the function of germination; we followed the young plant through the period of its growth, and examined the functions of digestion and exhalation, by means of which its nutrition was effected. We have pointed out the great forces which produce those physical and chemical changes, which result in the active phenomena of their life, and we have seen that the natural tendency of all the more obvious functions of the plant is to produce decay and death. But amidst the decay we have discovered a bountiful provision, whereby, although individuals die, the race is continued, and we have found that the face of the earth is for ever being renewed with the beauty and variety of vegetable life, by the constant reproduction of cells, which, although having no power of continuing alive by themselves, have a power of engendering life when they are

united. With these cells moves the finger of Deity; for in them resides the power of subjecting to the definite forms of species the material elements of which the magnificent variety of the vegetable kingdom is composed. EDWIN LANKESTER.

WILD FLOWERS.

Ye field flowers! the gardens eclipse you, 'tis true,
Yet, wildings of Nature, I doat upon you,
For ye waft me to summers of old,
When the earth teemed around me with fairy delight,
And when daisies and buttercups gladdened my sight,
Like treasures of silver and gold.

I love you for lulling me back into dreams
Of the blue Highland mountains and echoing streams,
And of birchen glades breathing their balm;
While the deer was seen glancing in sunshine remote,
And the deep mellow crush of the wood-pigeon's note
Made music that sweetened the calm.

Not a pastoral song has a pleasanter tune
Than ye speak to my heart, little wildings of June;
Of old ruinous castles ye tell,
Where I thought it delightful your beauties to find,
When the magic of Nature first breathed on my mind,
And your blossoms were part of her spell.

Even now what affections the violet awakes!
What loved little islands, twice seen in their lakes,
Can the wild water lily restore!
What landscapes I read in the primrose's looks!
And what pictures of pebbled and minnowy brooks,
In the vetches that tangled the shore!

Earth's cultureless buds! to my heart ye were dear,
Ere the fever of passion, or ague of fear,
Had scathed my existence's bloom;
Once I welcome you more, in life's passionless stage,
With the visions of youth to revisit my age,
And I wish you to grow on my tomb.

CAMPBELL.

Animal Physiology.

BY ROBERT JAMES MANN.

LESSON I.

THE BLOOD.

"He shall redeem their soul from deceit and violence: and precious shall their blood be in His sight."

1. The food, that is taken into the body of animals to renew the substance of the various organs, as this is wasted away by their vital activities, is digested in the interior of a cavity provided for the purpose. By digestion, its most nutritious and valuable parts are separated from the coarser ones, and then mingled with water, so that a smooth liquid is formed; which can be easily drunk in through the spongy walls it is placed in contact with. The digested and liquefied food, having been absorbed from the digestive cavity, is gathered up into a series of little tubes laid down for the purpose, it is then poured into one of the large blood-vessels, near to the heart, and there mingled with the general mass of the blood. The blood, indeed, is made out of the digested food. It consists of the nutritious part of that food, rendered soluble and mixed up with water; in order that it may be readily poured from the central heart, through the branching vessels provided for its distribution. Its materials are entirely derived from the food; but those materials are subjected to new influences when they get amongst the old blood, and are so re-arranged that they acquire new properties and characters.

2. If a little blood is taken from a pricked finger, and placed with a drop of water between two flat pieces of glass, a very thin fibre of it may be examined with the microscope. When this examination is made, it is found that the blood is full of little round bodies, most of them of a red colour, but a few quite pale and more or less transparent. These little bodies are called the *corpuscles* of the blood (from corpusculum, the Latin for a little body). These corpuscles are so very small, that three or four of them can lie side by side within

the breadth of a hair, and three or four thousand of them within the breadth of an inch. Not less than three million of them are contained in a drop of blood that may be taken upon the finest needle's point. Powerful microscopes, nevertheless, show that they are really hollow vesicles, composed of delicate transparent membrane, and filled inside with liquid. They are flattened, too, in one direction, so that some of them may be seen lying in the film, with their edges up towards the eye, while others present only their sides.

Fig. 1. represents the appearance of the human blood-corpuscles, when magnified a hundred and sixty thousand times. At *a*, they are seen with their sides towards the eye. At *b*, their edges are turned upwards.

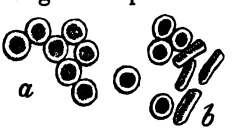


Fig. 1.

3. These corpuscles of the blood are living bodies, organized and planned for the performance of a particular office. It is their task to change the liquified food into the finished material, that is employed in the nutrition of the frame. They select various principles from the liquid in which they float, and along with which they run through all the branching vessels of the system, and then convert these principles in their own interiors into the rich, red substance that gives its colour to the blood.

When these corpuscles are taken away, the rest of the blood remains transparent and without colour. Now, it is the red material, contained within the corpuscles, and formed out of the other more crude blood constituents, by their agency, that supports and strengthens the muscles and nerves during their arduous labours. The red principle of the blood sustains the muscular and nervous energy of the living creature; and, in a general way, the amount of energy enjoyed is in strict accordance with the quantity of coloured corpuscles present in the circulating fluid. In conditions of ordinary health, about one pound, out of every seven pounds of blood, is formed of them.

4. The clear transparent fluid, in which the blood-corpuscles float, is termed the blood-liquor, or lymph (from

lympha, a Latin word for water). This lymph, however, is not pure water; it is thicker, and almost of a syrupy consistence. The thickness is due to the presence of a certain tenacious substance that is dissolved away in the lymph. When blood is allowed to flow from an opening made into the vein of a living animal, it issues in the condition of a uniform, red liquid, that cannot be discerned by the eye to be made up of different ingredients. After, however, the blood thus drawn has been allowed to stand quietly, for a little time, in a basin, it separates spontaneously into two parts; a red, firm mass which floats on the surface, and which is called the *clot* (from an old German word for *mass*), and a thin, clear liquid, which looks like whey, and which supports the floating clot. This clear liquid is termed the *serum*.

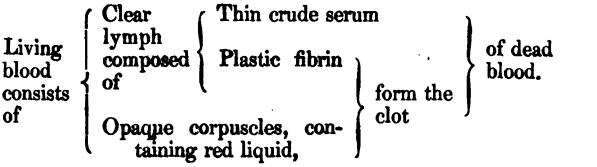
The clot contains all the red colouring principle of the blood, that is, it has in it all the corpuscles. But it possesses something besides, for the corpuscles are all connected together in it, into one substance. The hidden cause of this connection is made apparent when the clot is closely scrutinized with the microscope. It then becomes manifest that the corpuscles are all meshed together, by a series of pale, buff-coloured threads, which cross each other in all directions, and so form a densely-tangled mass. These threads are the thickening ingredients of the blood-lymph, separated from it at the instant of death,—and this ingredient has been denominated *fibrin*, in consequence of the manner in which it is arranged, when it is thus deposited from the lymph.

5. The fibrin of the blood is kept dissolved in the lymph, so long as the fluid is circulating in the living vessels; but it is of so plastic and tenacious a nature, that it coagulates (gathers itself together) into fibres, as soon as it is left free to follow its own tendencies. It is the fibrin of the blood that makes it viscid, and able to staunch accidental wounds inflicted on blood-vessels. Wounds get healed, in consequence of layers of tenacious fibrin being deposited on their edges, until the gap is filled up. Fibrin is so adhesi-

that comparatively small quantities of it are amply sufficient to render the blood plastic. The eighteen pounds of blood, that are present in the vessels of a human adult, do not commonly contain more than half an ounce of pure fibrin,—yet this small proportion is enough to make blood dry, like a varnish, when it is washed over any exposed surface. When there is less fibrin than this in the blood, however, wounds are very difficult to heal, and cuts bleed for long periods, without getting stanched; and if, on the other hand, there is more fibrin, as there always is when inflammation is present, organs are apt to get overloaded and clogged, which ought to be kept pervious and free.

6. Plastic fibrin, as well as the red liquid, is made in the blood, out of its rough material. Indeed, it is nutritive material on the verge of organizing itself. It only needs that it should be thrown out of the circulation, or that its quantity should be slightly augmented, and it consolidates itself at once. Even while it remains in the vessels, under ordinary circumstances, its great tenacity comes into play, for it then builds up certain structures of low vitality, that are intended, like gristle and tendon, to serve merely mechanical purposes. The microscope detects numerous pale corpuscles among the coloured ones: in all probability, these pale corpuscles are charged with the task of forming fibrin, just as the coloured corpuscles form the red liquid, for they always become more numerous whenever the proportional quantity of fibrin is greatly augmented, and they seem also to associate themselves intimately with the fibrin in various other ways. Blood thus consists of crude nutritive matter, and manufactured produce (red liquid and fibrin), together with the little operatives that are engaged in the manufacture (corpuscles, coloured and pale), all mixed up in one stream. The serum that is left after coagulation has taken place out of the body, consists of the crude nutritive matters dissolved in water, —and the clot contains the perfected matters, the red liquid and fibrin, as well as the corpuscles. The blood-lymph, while yet in the living vessels, is composed of the serum thickened by the fibrin, for plastic purposes.

The relations of these several constituents to each other, in living and dead blood, may be expressed for the sake of clear illustration in the following tabular form:—



7. The serum very nearly resembles a weak solution of "white of egg," with a small quantity of saline and mineral matter dissolved in it. When it is heated to the temperature of boiling water, a white cloudy substance falls to the bottom of the containing vessel, which is strictly identical with "white of egg," coagulated by heat. This substance is termed *albumen*, such being the Latin name for "white of egg," and *it*, in reality, is the crude nutritive material, out of which the red liquid and fibrin are fabricated by the corpuscles. *Albumen* is merely the nutritious portion of the food, rendered soluble by digestion. It is not made in the blood; it is introduced ready prepared. Albumen is contained in every kind of food that is consumed, to any plastic purpose, by animals. In the egg, this crude nourishment is stored away round the yolk, for the support of the growth of the young bird, during the earliest stages of its life. During the more advanced stages of life, it is constantly added to the circulating blood in fresh quantities, as its presence is required.

8. The saline and mineral matters, that are mingled with the albumen in the serum, in very small proportions, are also designed for constructive purposes; there is, however, this difference between them and the albumen, each of them makes its own contribution to particular structures, but the albumen furnishes a framework for all structures alike. Thus, there are amongst the inorganic constituents of the serum, lime that goes to strengthen the bones, phosphorus that is destined to make the nerves and brain fit for their work, sulphur and salt that mingle with nearly all the albuminous ar

fibrinous fabrics, potash that helps to string the muscles, and soda that aids in converting refuse combustible matters into soapy bile. The eighteen pounds of blood contained in the vessels of a living man, have in them, at one time, about eleven ounces of albumen, and two ounces of inorganic ingredients. Such small proportions are sufficient for all useful purposes, because these substances are constantly being poured into the blood, in fresh supplies, as fast as they are removed.

9. But the blood, in addition to the plastic matters that are destined for the nourishment of the living organs, contains also a small measure of fuel devoted to the preservation of the heat of the body through the process of burning. The fuel of the blood is the oily and sugary matters derived directly from the food and the bile furnished by the liver: very small proportions of these combustible matters are sufficient for the preservation of the proper temperature; eighteen pounds of blood, under circumstances of ordinary health, contain scarcely more than half an ounce of oil and bile. When the oil furnished from the food amounts to more than this it is taken out of the blood and stored away as fat; redundant bile is at once thrown out of the system as refuse matter that can be altogether dispensed with at the time.

LESSON II.

WATER IN THE ANIMAL SYSTEM.

"He drinketh no water and is faint."

1. WATER being a liquid, is on this account peculiarly fitted as an agent for the transport of solid materials: things mixed up amidst its particles may be carried in all directions by its streams. But it also possesses a remarkable property which makes its transporting power of singular value in a practical sense. It is more neutral and indifferent than any other liquid that is known; very many substances can be completely dissolved away amidst its particles without having their own characters altered in any appreciable degree. Thus, when sugar is dissolved in water it still presents its distinctive sweetness to the taste, and salt still preserves its saline

savour when in solution. Both the sugar and salt also are recovered, in all their original perfection, from solutions in water, as soon as the watery fluid is driven off from them by heat. Watery solution seems to stand midway between chemical union, in which the properties of the combining bodies are altogether changed by the act, and mere mechanical admixture, in which the particles of the mingled bodies are only loosely intermixed. It confers all the advantages of the close intimacy of the one without entailing the necessity of modification of character which attends the other. Water could never have carried bodies mixed with it through minute channels and pores unless the union had been a very close one; but, at the same time, it would have been to little purpose that it should be intrusted with the conveyance of such bodies, unless it could bear them honestly to their destination without depriving them of any of their essential properties by the way.

2. Out of the eighteen pints of blood that are contained in the vessels of a full-grown man, nearly fifteen are pure water. But the various substances that are mingled together in this water are in no way affected, in their sensible properties by intimate association with it. They are all merely carried by it, in all their completeness, into the positions in which their presence is required. Water, however, does not make an end of its work when it has circulated nutritious material through the body; it then lends its aid to convert that nutritious material into living structure, and to keep it in the condition in which its several vital offices are the most easily and efficiently performed. All vital organs are made of very soft substance, and contain a great deal of water in their composition. In a man of twelve stones' weight, the liquid blood does not amount to more than one stone and a quarter, but not less than eight of the twelve stones are nevertheless made up of pure water. When different kinds of substances are dissolved together in water, their particles are kept so near together that they are very favourably situated for influencing each other mutually, although the indifference of the water prevents its effecting any changes

in them chemically: most of the operations of life depend upon the exercise of such mutual influences between different kinds of bodies.

3. But water not only carries nourishment to active organs, and then assists them to perform their labours of transformation, it also conveys away the waste that is necessarily made during the work; it takes up refuse matter and pours with it out of the system through certain sewer-like channels provided for the escape; these channels constitute the secreting, or separating organs. In this way a constant drain of water from the blood is kept up, and if there were no plan adopted to make good this loss, almost as soon as it occurs, the blood would soon be made too thick for the purposes of circulation. The loss is supplied by taking fresh liquid into the stomach from time to time. So soon as the blood has acquired a certain degree of thickness, the uneasy sensation termed thirst, is experienced. Admonished by this sensation the thirsty animal drinks, and some kind of thin liquid, containing a large proportion of water, is placed in contact with the walls of the digestive cavity, through which the thickened blood is coursing in its capillary vessels; the blood then attracts the thin liquid to itself through the delicate permeable membrane that alone divides the two substances, and thus gets its proper degree of fluidity restored. Water thus carries nourishment, forwards nutritive operations, and removes waste matters from the living system.

4. But, in addition to this, it keeps guard over the temperature that is most suitable to the offices of life, and prevents it from being at any time raised too high for the safety or the comforts of the creature. In this respect water forms an antagonistic principle to the fuel of the blood.

5. Whenever water is changed into vapour, heat is taken up into the vapour and hidden away in an inappreciable form; but vapour is always exhaled from the surfaces of moist bodies whenever they are exposed to the air, provided only that air has not already the full charge of vapour in it that it is able, at the existing temperature,

to hold. As moist bodies exhale vapour when exposed to the air, and as vapour when it is formed takes up and consumes heat, moist bodies are always rendered colder by exposure. The moisture is converted into vapour and escapes, but it, at the same time, carries with it heat that had before been active in preserving, in the body, a certain degree of warmth. Now, living animals are moist bodies; hence, water is being continually poured off from them, in a state of vapour, into the air; and they are continually being cooled by the vapour they lose. But the amount of cooling that is effected in this way of course is exactly in proportion to the quantity of vapour that is removed: under ordinary circumstances about two pounds and a half of substance are exhaled from the surface of the human frame every twenty-four hours; but, under especial conditions, twice as much may be lost.

6. The skin is covered on its surface by layers of little dry scales, which tend to prevent evaporation; but a vast number of small pores are left at intervals, opening out between and amongst these scales. Now, when the skin gets very warm, the capillary vessels that run through its under surface, become relaxed, and the liquid blood flows freely and abundantly through them; at the same time the little pores, that lie among the dried scales, get opened, and, in this way, an increased facility is afforded for evaporation. But when, on the other hand, the skin is chilled, the vessels become contracted and the pores closed, and so evaporation is checked. As in the steam-engine too high a pressure of steam opens the safety-valve and allows the redundant vapour to make its escape; too high a degree of warmth in the blood of the living body opens the pores of the skin and allows the redundant heat to fly off on vaporous wings.

7. Perspiration, that is, the exhalation of vapour from the skin, is therefore the operation by which the process of cooling is regulated: it is increased whenever it is necessary that more heat should be removed from the system; it is diminished whenever economy, rather than diminution of heat, is the thing required.

LESSON III.

STRUCTURE OF THE SKIN.

"Thou hast clothed me with skin and flesh, and hast fenced me with bones and sinews."

1. THE various organs that compose the animal body are all bound up together by a firm external investment which is called the skin. This skin is formed of a quantity of strong fibres densely interwoven together, and crossing each other in all directions. In the under part of the layer these fibres are loosely placed, and intermixed with little masses of fat; but, in the upper part, the texture is fine and close. The thickness of the skin varies in different parts of the body, according to the degree of resistance that is required of it; in some places it amounts in man to nearly a quarter of an inch.

2. But a variety of circumstances renders it necessary that the skin of animals should be sensible as well as strong. It would not at all do that the vital organs should be shut out from all knowledge of what is taking place around them, for it is often necessary that their position in regard to external things should be modified from time to time. The external surface is hence made to be an inlet for impressions. Information regarding surrounding arrangements is conveyed through it to the centres of perception; the organs of special sense receive and transmit many of these messages, but the entire tract of the skin is able to tell a great deal concerning bodies that are in contact with it. A multitude of little nipple-shaped points project up from its outer surface; these are called papillæ (from the Latin word for nipple). In figure 2, *f f* represents the fibrous portion of the skin, and *n n* the nipple-shaped points that project from its outer surface. These papillæ are from the one to the two hundredth part of an inch high; that is, one or two hundred of them might be piled on each other in the extent of an inch. Delicate nerve-threads

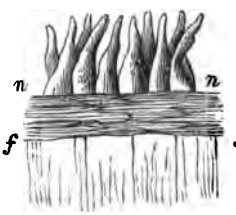


Fig. 2.

come from the spinal cord into the skin, and are then mixed with its interwoven fibres, and at length pass out from among them into the papillæ. Figure 3 is a sketch of the final branch of a nerve-thread, thus distributed to one of the nipple-shaped points. In consequence of the presence in them of these nerve-fibres, the papillæ are the seat of the sense of feeling. Whenever resisting bodies are pressed against their terminations, the nerve-threads are sensible of the pressure, and take notice of it, transmitting the sensation as an impression of touch.

Fig. 3.

3. The papillæ of the skin are so acutely sensitive to impressions, that when any hard body is placed in immediate contact with them the sensation amounts to absolute pain. On this account, Nature has furnished them with a series of little shields, which at once protect them from injury, and lessen the force of the impulses made on them. Several layers of little vesicles are placed between their sides and over their extremities: the innermost rows of these vesicles are soft and moist, but the outer ones are flattened and dried into a sort of horny consistence. Together these constitute what is termed the cuticle, or scarf-skin.

Neither blood-vessels nor nerves penetrate into the scarf-skin; portions of it may be cut away without any sensation being produced, or blood drawn; a needle may be pushed quite through its thickness without being felt. When a blister is applied to the skin, it is this insensible structure which is raised from the true skin beneath, by the serous fluid that is poured out: as soon as a portion of the elevated layer is removed, the liquid escapes, and the points of the papillæ are left uncovered and exposed. The service rendered by the *insensible cuticle*, in blunting the sensation of the *papillæ*, is remarkably illustrated by the pain that is *experienced* upon its removal; contact with even the *soft and elastic* air, under such circumstances, causes considerable smarting, and the pressure of any rough,

hard body changes the smarting into very decided torture. The insensible scarf-skin defends and protects the sensible skin that is spread beneath it, very much as a glove defends and protects the hand. Figure 4 is a sketch illustrative of the structure of the outer insensible layer of the skin: *c c* are the newly-formed vesicles that are nearest to the sensitive papillæ; *s s* are the older vesicles that have been pushed on towards the surface, and that have dried from exposure, until they have been changed into flat horny scales. The new vesicles, *c c*, are formed out of a thick, plastic liquid, poured from the contiguous surface of the sensitive skin; successive crops of them are constantly in process of production, and the oldest layers are thrown off from the surface in the condition of scurf, as fast as the new ones appear. Sometimes, when great protection from the influence of cold is needed, clusters of them are kept adherent, and are moulded together into thickly-planted cylinders, to constitute what is known as hair and fur.

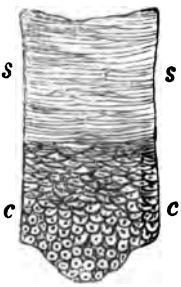


Fig. 4.

4. The scarf-skin, however, needs to be kept somewhat in order, that it may remain fit for the protective office it has to perform. In consequence of its constant exposure to the atmosphere it dries very rapidly, and, if no provision were made to obviate the result, it would soon get so rigid and horny that it would be altogether unsuited for the task of transmitting impressions of touch to the sensitive papillæ that project beneath in amongst its under-scales; this, however, is not allowed to happen. The protective scarf-skin is kept supple and yielding by means of a very ingenious contrivance: small pits are hollowed out into the substance of the fibrous layer that lies beneath, and, by the side of these pits, little clusters of vesicles are placed, which extract from the blood a peculiar oily substance, that is then poured out amidst the scales of the scarf-skin: very commonly hairs escape through the same openings that give passage to

the anointing oil. In figure 5, *h* shows the appearance of a hair, escaping through a canal, hollowed out for it in the skin and cuticle; *a a* are the clusters of vesicles that secrete the anointing oil, with the small channels of communication that convey the secretion from them into the space that surrounds the hair.

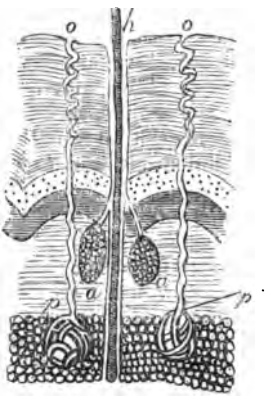


Fig. 5.

5. The layer of dry scales, furnished for the defence of the sensitive papillæ of the skin, tends to prevent all evaporation from its surface, and this the more certainly because of the oily liquid with which it is dressed. But it has been already shown that vapour does pass out through the skin in large quantities, and that, in fact, the skin is made to regulate this amount according to the necessities of the time, now increasing it, that the body may be cooled by the evaporation, and now diminishing it, that the cooling process may be checked. The passage of vapour is effected by a vast number of little pores, or mouths, that are pierced through the cuticle. Fig. 6 represents the appearance these pores make when examined by a magnifying glass. In most parts of the skin there are some two thousand of these pores upon an area that would be covered by a shilling.

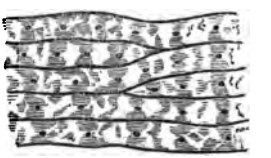


Fig. 6.

6. From each perspiration-pore, a delicate tube passes down through the substance of the skin, until it reaches the under surface; it then gets coiled up and knotted, as represented at *p p* in fig. 5 (*o o* being perspiration-pores). The knotted part lies in the midst of fat, and is furnished with a great abundance of blood-vessels, which distribute delicate-looped branches

over the sides of the tube. While the blood courses through the vessels, portions of its thinner part exhale into the tube, as water exhales from a piece of wetted linen, and then pass out through the external pore as vapour. By far the larger amount of the perspiration is invisible vapour, when it escapes from the skin; but, if, at any time, its quantity is very much increased, it is thrown out so rapidly that it collects over the pores in liquid drops, and at last even runs down the skin in streams. The water of the perspiration contains a little solid matter dissolved in it; sometimes as much as one per cent. This is chiefly of the nature of waste material that has performed its office in the economy, and now needs to be removed from the position in which it is of no further use.

7. Thus, then, although the skin is plastered over by a dense layer of dry, and somewhat oily scales, that is in itself nearly impervious to moisture, an arrangement is made, that insures a certain amount of transpiration through it. The liquid blood is caused to circulate beneath it, amongst, and around coiled-up tubes, and these coiled-up tubes pierce through the otherwise impervious cuticular layer, and end in open mouths. If the entire surface of the body had been pervious to moisture, the liquid part of the blood, and other fluids, would have continually evaporated from it, with a rapidity that would have only varied to a small extent in accordance with the different degrees of heat and dryness in the surrounding air. But, by causing the evaporation to take place into pipes situated beneath an impervious coat, and only opening through it, at particular places, by mouths, great command of the process is gained. The opening or closing of the mouths at once augments or diminishes the loss of vapour. Each little knotted-up tube is not more than a quarter of an inch long, when disentangled and unrolled; but there are nevertheless so many of them scattered beneath the skin, that the entire system of perspiration-tubing, there distributed, becomes altogether of very enormous extent. The palm of a moderate-sized hand cannot be furnished with less than five hundred feet of perspiration-

pipes. It has been calculated that the body of a man of ordinary size, has seven millions of perspiration-pores distributed over its surface, and that the exhaling tubes, which are in communication with these pores, are collectively twenty-eight miles long! Through these twenty-eight miles of tubing, with their seven millions of mouths, a vapour-like exhalation is continually streaming in greater or less amount: no wonder, therefore, that sometimes as much as five pounds of liquid are lost to the body, by this outlet alone, in twenty-four hours. Fig. 6 is a magnified view of the pores on the palm of the hand.

8. The skin, in common with all the other structures of the body, must be nourished. All its complicated apparatus of fibres, and nerves, and secreting tubes, and vesicles, must be daily supplied with blood. This supply is effected by means of a network of fine vessels, that are distributed everywhere amidst the interwoven fibres of the sensitive layer of the skin, and that send up loops even into the papillæ, but not into the layer of insensible cuticle that overlies them. Fig. 7 is a magnified view of the netted blood-vessels of the skin as they are seen when the rest of the structures intermingled with them are removed. These netted vessels are so finely and so abundantly distributed in the skin, that the point of the finest needle cannot be inserted among them without wounding some of them, and allowing an escape of their crimson contents.

Fig. 7.

9. Such is the external covering of the animal frame. Simple as it looks, it is really a structure of the most complex kind, ingeniously planned for the performance of a variety of offices, and fulfilling the purpose of its design, in a very wondrous way. It is, in the main, a firm and resisting coat, densely woven out of the toughest fibres; but in the midst of the fibres of this dense coat, nourishing blood-vessels are scattered, and sensitive nerves are spread. Outside the nerves and fibres, a thatching of insensible scales is laid, which is

sometimes extended into a thick crop of hair, when at any time it is required that heat should be kept from passing too rapidly out of the system. Beneath the insensible thatch, little flasks are inserted for the preparation of an oil, to be used in softening its substance; and under the skin itself vaults are burrowed, which are charged with vaporous exhalations from the blood, and which pour those exhalations out through countless openings, tunnelled out to the external air. Blood circulates in copious streams through all these multifarious pieces of contrivance, and furnishes at once sensation to the nerves, vapour for the exhaling vaults, and scales and oil for the protective layer.

LESSON IV.

CLEANLINESS AND TEMPERANCE.

"Wine is a mocker, strong drink is raging; and whosoever is deceived thereby is not wise."

1. NATURE has deemed it necessary to construct twenty-eight miles of vaulting, beneath the dense structure that forms the external covering of the human body, and to furnish seven millions of openings to this vaulting, in order that the vapours, which are therein separated from the blood, may be freely poured away. From two to five pints of liquid are converted into vapour in these vaults, every twenty-four hours, and are then steamed forth, by the seven million of apertures. But this vapour is not altogether pure water; it is loaded with a certain amount of denser matter, which is waste from the various living structures. From half an ounce, to an ounce, in every five pints of perspiration, is waste substance of this kind.

2. The pores, that open out from the perspiration-vaults of the skin through its substance, are of an incredibly-minute size, notwithstanding the large quantity of matter they allow to pass through them. They are so small that they cannot be seen at all, unless the most powerful microscopes are used in the observation. These small pores obviously may be easily choked up, and closed. The minutest speck of tenacious substance is sufficient to render several of them impervious, so long

as it adheres. When perspiration is poured out on the skin in a liquid form, its watery portion soon evaporates, but in doing so, leaves behind it the denser and less volatile matters that were associated with it. A thin layer of gummy impure substance is thus spread over the skin, and mingles itself with the oil poured out for the softening of its external layer.

3. The frequent change of the linen, worn next to the skin, serves to remove the greater portion of the impurities left by the perspiration. It absorbs them into its own interstices, so soon as they are again rendered moist by fresh exhalations, and it rubs and polishes them off, when it is moved against the cutaneous surface, carrying layer after layer of the dried cuticular scales with it. But nature has laid her plans on the whole, in the knowledge that water is one of the most abundant and easily-procured agents that are so beneficently scattered over the world. Animals in the natural state instinctively seek the river, or the pool, and wash themselves in its cleansing waves. The bird shakes out its soft plumage beneath the rain, or makes a mimic shower for itself out of some accidental puddle. Savages swim almost as soon as they walk. Some men lose this instinct of nature, when they live in the artificially-formed habits of society, but then their reason enables them safely to dispense with the simpler guide. They learn that health and personal cleanliness are inseparable from each other, and that they must follow the example set them by the lower creatures, if they intend to remain vigorous and strong.

4. The delicate pores of the skin, which are designed to allow vapour and refuse exhalations to pass through, cannot be preserved in full activity, unless they are perfectly cleansed, at frequent intervals, by the free use of water. When the bath is not employed every day, the skin gets more or less harsh and impervious, instead of being soft and affording free passage to vapour. The system then remains unduly heated, during seasons of warmth, and the blood gets impure, from the accumulation of waste that ought to be removed. But, when the pores, intended for the escape of exhalation from th-

blood, get choked, the vessels that are in communication with those pores, become also overcharged, and the circulation is rendered sluggish and dull. Bathing is essential to comfort and health; because it keeps the skin in the most favourable condition for the full performance of its important feeling, cooling, and purifying functions. When the skin is neglected, and not thoroughly cleansed, at least daily, by the free use of pure water, it grows harsh, the circulation in its vessels becomes languid, and its proper sense of feeling is blunted, and changes into chilly and irritable sensations. When, on the other hand, it is taken proper care of, it is always soft and warm, and filled with a most agreeable feeling of freedom and glow.

5. TEMPERANCE.—Drink is taken for the purpose of supplying the liquid that is needed to carry nourishment into the system, and to keep that nourishment circulating through the various vessels, to the different parts of the living frame. All animals, excepting man, use pure water as their beverage. Man employs various liquids, that are chiefly composed of water; but that also contain certain other principles dissolved or suspended in it. So far, however, as the main objects, for which drink is required, are concerned, it is the water alone of these liquids that is serviceable. This it is that renders the digested food transportable; that carries its various nutritious principles to the spots in which they are needed, that facilitates their change into structure, that washes away all refuse and waste; and that cools the overheated frame, by setting up evaporation from its superficial pores. Indeed, it may be stated, as a general rule, that the admixture of other things with water, before it is swallowed, impairs rather than aids its value as a drink. Water, that is already loaded with soluble substances, is not in the best-possible state for taking upon itself the transport of the nutritious portion of the food.

6. The various fermented liquors are used by men for drink, in place of pure water, because they produce certain agreeable sensations when they are swallowed. The cause of these sensations is the presence in the liquid of

a certain quantity of a peculiar substance, that was first examined by the Arabian chemists, and was called by them alcohol. Alcohol is merely sugar, that has been taken one stage backwards, from the state into which it has been raised by the constructive powers of vegetable life. It is formed out of sugar, by fermentation, which is merely a process of slow decay. Some of the material atoms, contained in the sugar, fly off as vapour and carbonic acid, and the rest are subjected to a new arrangement, which alters their specific characters. They cease to form a sweet substance, and become instead, a spirituous one, possessing a hot taste, and other distinctive characters.

7. The peculiar spirituous compound, that is made out of sugar, by fermentation, is itself a liquid, and mixes readily with water. Indeed, it has so strong an affection for that limpid fluid, that it can hardly be procured without the presence of some few aqueous particles. What is called absolutely alcohol is very strong; but it still contains two per cent. of water. In consequence of this property, strong alcohol dries moist substances almost as heat would; meat, when placed in it shrivels up just as it would do, if left in some dry and warm situation. The various fermented beverages, employed by man as drinks, are all watery solutions of alcohol. Whisky, brandy, and rum, are more than half alcohol. Port, and sherry wine, contains one-fourth part of it. Porter and ale, have one or two parts of it in each hundred parts. And small beer, one part to every thousand parts.

8. All substances, that are *thoroughly dissolved* in water, are taken up into the vessels of the stomach as readily as the purest water itself. Hence, when an admixture of alcohol and water is swallowed, both the ingredients at once find their way into the blood. When in the blood, they of course both flow, with its streams, to every part of the living frame. But the alcohol is not one of the ordinary and proper ingredients of the blood. It is never found in the vital stream of any of the lower animals, neither is it always present in that of man himself. Thousands of people live through long lives of uninterrupted health, without ever admitting one drop

of it into their systems. Nature, therefore, has to get rid of it out of the blood, as fast as she can. She can make no use of it, because it has no plastic capacity of its own. But it fortunately happens that she can turn it out of the way. It is itself of a very combustible nature. It contains, indeed, more of the combustible principles, carbon and hydrogen, than sugar. Sugar has in it 48 per cent. of combustible matter; but alcohol has as much as 65 per cent.

9. Whenever alcohol is received into the blood, it is served, then, as other combustible principles are. It is subjected to the influence of the oxygen that is taken in by respiration, is converted into vaporous carbonic acid and water, and is so exhaled at each expiration from the lungs. The rapidity with which spirit is in this way, removed from the circulating fluid, is scarcely less surprising than the readiness with which it is imbibed. When greatly diluted wines are drunk very slowly, and abundance of pure air is breathed, during the time, alcohol escapes by the lungs, almost as quickly as it is absorbed from the stomach. This is one of the wonderful illustrations so often afforded, in the animal economy, of the care that is taken to remove useless and noxious influences, before they can be operative, to any great extent, for harm.

10. If, however, alcohol is more rapidly imbibed into the blood than it can be burned away, under the air-blasts of respiration, it accumulates more and more in the vessels, and very peculiar effects soon begin to ensue. First, it stimulates all the vital organs to increased exertion. The heart beats more quickly. The skin becomes hot and exhales more freely. The eyes grow bright, the features get flushed, and the thoughts flow with unusual facility. Soon, however, something beyond mere excitement appears. The thoughts not only flow freely, but they seem to go too fast for the control of the will. It is no longer possible to direct them to any desired end. They gain expression in incoherent words. Imagination runs riot, and reason and judgment sleep. The fact is simply this: —The nervous material and brain-substance of the

body attract alcohol to themselves, with greater determination than any of the other structures. When animals are killed, immediately after large quantities of alcohol have been introduced into their stomachs, more alcohol is found in their brains, than in any other part of equal size. But nature never designed that there should be alcohol in brains. If she had, she would have placed it there invariably and impartially. The brain is, in truth, oppressed and disturbed by the unusual presence, when it comes. But its highest and most delicate powers suffer the most and first, as it might be expected that they would. The intellectual faculties become impaired, even while the other operations of the nervous system continue to be duly and properly performed.

11. Alcohol is a poison, then, when introduced into the living blood, and produces its injurious influences by interfering with the structure and condition of the nervous substance, to which it is carried in the course of the circulation. The first symptoms of the poisoning are a quickened circulation, a flushed face, an excited state of mind, and rapid incoherent conversation. If, when this state of affairs has been produced, no more of the poison is imbibed, that portion, which has attached itself to the nerve-substance, is slowly taken up from it by the circulating blood, and then burned off through the process of respiration. The organs, that have been over-excited, sink into a depressed and languid condition. The pulse becomes weak, the skin dry, and the mind lethargic. A few hours of repose follow, and the system then reassumes its ordinary tone. If, however, on the other hand, more of the poison be admitted, the mischief advances with a rapid pace. All reasoning power, and all faculty of personal control disappear. Instinct and passion usurp the rule that ought to be held by the judgment. Then, even instinct falters, the domain of sensation is invaded. Giddiness, and all kinds of strange sounds, and odd sights and illusions, are experienced. The eyes get vacant—the face grows pale, the muscles tremble, the limbs refuse to perform their office; and at last the drunkard sinks into a heavy stupor, and all the privileges of conscious life are in abeyance for the time.

When the powers of the mind are impaired, in consequence of the presence of alcohol in the blood, the state is said to be one of intoxication; and the word is particularly well suited to express the condition, for it is derived from the Latin *toxicum*, which signifies poison. To be intoxicated is, in simple truth, to be poisoned. It may be that the great majority of drunkards recover from the state. The noxious agent is of so volatile a nature, that so soon as all further supply of it to the blood is stopped, in consequence of the inability of the drinker to swallow any longer, it begins to escape through the lungs, and thus the overcharged blood gets relieved from its presence, and the nervous oppression is gradually removed. Still, the recovery under such circumstances, is always from a position of extreme danger. It requires but a few drops more of the alcohol in the blood, after sensation has been suspended, to extend the deadening influence to the spinal cord, which has the charge of the respiratory movements; and then, the play of the chest is arrested, dark venous blood flows through all the channels of the frame, in the place of bright arterial blood, the paralyzed heart makes a few laborious throbs as a final effort, and the sleep of insensibility becomes the sleep of death.

12. If, however, in consequence of the natural power of resistance the body is endowed with, the drunkard is able to continue in the indulgence of his vicious habit for some time, and does escape from the dangerous state in which he has, of his own free will placed himself, again and again, the penalty of his culpable folly is still not avoided, it is only postponed for a season. A sober man, at the age of twenty years, has very reasonable ground to anticipate the enjoyment of forty-four more years of life, but the confirmed drunkard at the same age, cannot expect to live more than fifteen years. The strong-looking young man of twenty years of age, if he has contracted uncontrollable habits of intoxication, is really a dying man in spite of appearances. He may be dying slowly perhaps, but he is dying, before his natural time, none the less surely. He may, through the chapter of accidents over which he has himself no

control, recover very frequently from the fits of degrading and disgusting stupor, into which he allows himself to be plunged, but even if he does so, he pays a certain penalty in addition to the direct misery that he experiences. That penalty is the momentous one of twenty-nine years of life.

13. Drunkards kill themselves prematurely, by the poisonous agent they perversely introduce into their blood. But none of the obvious effects of alcoholic poisoning, alluded to above, are produced when fermented liquors are used in moderation, instead of in excess. It does not, however, of necessity follow that they do no harm under such circumstances. It is perfectly clear that alcohol is of no constructive use in the frame. Nothing can be built up out of it. On this account alone it should be viewed with suspicion, for redundant matters can hardly be other than harmful, in a case where the natural state is one of delicately-adjusted balance. But alcohol is combustible, although it is not nutritious. It is got rid of by being burnt away, as we have already seen. Hence it may be employed as a fuel. But here there is an element of danger, for Nature has made her own arrangements for the warming of the body, independent of all alcoholic supplies. The system is kept at the right temperature in the lower animals that drink no spirit in any form. Alcohol is so good a fuel, that it gets itself burned in preference to most other combustibles, when it is exposed with them to suitable conditions. If a piece of paper be moistened with spirits of wine, the spirit will burn off when set light to, but the paper will remain untouched, in the midst of the flame, until all the spirit has been consumed. Just the same thing happens when alcohol is mingled with the combustible principles of the blood. It is burned away under the blasts of the respiration, and they are left. The temperature of the body is kept up by the alcohol, and the proper fuel of the blood is saved, but the saving is to a mischievous end, and not to a good one. The dense matters, that ought to be burned away, accumulate more and more in the blood, so long as there is alcohol to take their place, and, in this way,

the circulating fluid gets overcharged with carbon, and deranged by its presence.

14. Alcohol rouses the vital organs to make increased exertion. A glass or two of wine often augments the appetite, and quickens digestion. But even this is not of necessity a beneficial action. When the stomach, the heart, and the lungs are doing their work well, and healthily, they do not need to be made to do it more than well. If they are so, more blood is formed than the system requires, and this too abundant blood is kept constantly circulating to all parts, and every organ has to struggle against the tendency to congestion and inflammatory stagnation that the preternatural fulness induces. If they struggle successfully for a time, they accomplish their tasks at the expense of subsequent exhaustion, for work is then taken out of them to-day, which ought not to be asked of them until to morrow, and, on the morrow, the overstrained and weakened organs are unequal to even the same exertion, unless still more powerfully goaded. It is the nature of all stimulants to lose their influence from habit, so that more and more of them is continually required, for the production of any given result. Hence, when alcohol is habitually used for the sake of the excitement it effects, there is a constant tendency to increase the quantity consumed, until its intoxicating as well as its exciting properties come into play. So long as fermented liquors are used in moderation, the preservative power exercised by nature is such, that, in the great majority of cases, all their alcohol is separated from the blood, without any obvious mischief being produced by its presence. Still, as that alcohol is of no use in a plastic point of view, as it takes the place of the fuel which Nature supplies for the support of the animal temperature, and as it stimulates the vital organs to a degree of exertion that may be injurious, and that may ultimately lead to derangement, there can be no doubt that he is altogether the wiser man, who entirely abstains from even that moderate use. Spirits and wine are best labelled as physic, and kept on the doctor's shelves.

R. J. Mann.

LIFE.

Oh Life! I breathe thee in the breeze,
I feel thee bounding in my veins,
I see thee in these stretching trees—
These flowers, this still rock's mossy stains·

This stream of odours, flowing by
From clover-field and clumps of pine,
This music, thrilling all the sky,
From all the morning birds, are thine.

Ah! must thy mighty breath, that wakes
Insect and bird, and flower and tree,
From the low-trodden dust, and makes
Their daily gladness, pass from me—

Pass, pulse by pulse, till o'er the ground
These limbs, now strong, shall creep with pain,
And this fair world of sight and sound
Seem fading into night again?

The things, oh Life! thou quickenest, all
Strive upwards toward the broad bright sky—
Upward and outward, and they fall
Back to earth's bosom when they die.

All that have borne the touch of death—
All that shall live—lie mingled there,
Beneath that veil of bloom and breath,
That living zone 'twixt earth and air.

There lies my chamber, dark and still,
The atoms trampled by my feet,
There wait, to take the place I fill
In the sweet air and sunshine sweet.

Well, I have had my turn, have been
Raised from the darkness of the clod,
And for a glorious moment seen
The brightness of the skirts of God;

And knew the light within my breast,
Though wavering oftentimes and dim,
The power, the will that never rest,
And cannot die, were all from Him!

Bryant.

Natural History.

BY ROBERT PATTERSON.

LESSON I.

SUSTENANCE OF ANIMAL LIFE.

"The eyes of all look'd up to Him whose hand
Had made them, and supplied their daily need;
Although they knew Him not, they look'd to Him;
And He, whose mercy is o'er all His works,
Forgot not one of His large family,
But cared for each as for an only child.
They plough'd not, sow'd not, gathered not in barns,
Thought not of yesterday, nor knew to-morrow;
Yet harvests inexhaustible they reap'd."

MONTGOMERY'S *Pelican Island.*

1. ON one occasion in early spring, I got into London on a Friday evening, fatigued after a long journey, and retired to bed at an early hour, in the Tavistock Hotel, Covent Garden. My sleep at first was sound and unbroken, but gradually strange sounds, rumbling noises, and the murmur of human voices, mingled with my dreams, and I awoke. All was not illusion: the visions had passed away, but the sounds continued. What could they be? I listened for a minute, then springing from my bed, looked from the window of my room on one of the strangest sights, that even London can present to a stranger.

It was only four o'clock; but instead of the darkness and solitude which we associate with that early hour, the whole of Covent Garden Market was brilliantly lighted, crowded with men and women, and blocked up with vehicles of many kinds, among which were ponderous waggons piled high with vegetables. After gazing in wonder on the unaccustomed scene, I again went to bed, and fell fast asleep. On coming down stairs at nine o'clock, I found the wondrous spectacle of the early morning had disappeared, and the Market had assumed its usual day-time aspect.

2. Often since then have I looked upon that scene, and marked its varying features; which indicate the change of the seasons with unerring certainty. It

exhibits the earliest vegetables of spring, the first fruits of summer, the mellow produce of autumn, and the hardy children of winter. Whence is this great and perennial supply derived?

The market gardens in the neighbourhood of the metropolis, stimulated by skilled labour, and abundance of manure, to yield three, four, and even five crops in the year, furnish of course a large portion. Those mighty waggons, with their skilfully-built mounds of vegetables, come in during the night from localities within a few miles of the market. But in addition to this home supply the night trains convey by railway the produce of remote counties; and steamers from France, Belgium, and Holland pour in their contributions. And thus, while the great merchants of the city, and the lordly dwellers in Belgravia, are wrapt in slumber, the greengrocers who are to supply the vegetables for their next dinner, and the fruits for the dessert, are here selecting these necessaries and luxuries from a stock collected from far and near.

3. A writer in Dickens's 'Household Words' states "that six or seven hundred thousand pottles of strawberries; forty or more millions of cabbages; two millions of cauliflowers; three hundred thousand bushels of peas; seven hundred and fifty thousand lettuces; and half a million bushels of onions, are sold here annually. And that the amount of money paid yearly for fruits and vegetables in this market, cannot be less than three millions sterling."

Yet fruit and vegetables constitute but one portion of the Londoner's bill of fare, and Covent Garden but one of five marts, though by far the greatest. An able writer in the 'Quarterly Review' for September, 1854, who seems to have taken great pains to arrive at correct conclusions, gives us some statements that enable us to compare the consumption of fish, flesh, and fowl with that of vegetables.

He informs us, on the authority of Mr. Mayhew, that four hundred thousand live cod, and about the same number of salmon and salmon-trout, annually make their appearance in the London market. These numbers

though considerable, sink into insignificance when contrasted with those of their more diminutive allies. Thus we have opposite to—

Soles	97,520,000
Plaice	33,600,000
Fresh Herrings . .	175,000,000
Herrings in bulk . .	175,000,000

Under the common, though, zoologically speaking, not very accurate denomination of 'Shell-fish,' we have—

Oysters . . .	495,896,000
Lobsters . . .	1,200,000
Crabs	600,000
Periwinkles . . .	304,000,000

4. The same writer, after giving many particulars regarding the quantities of butcher's meat, game, and poultry, remarks:—"The inability of figures to convey an adequate impression to the mind of the series of units of which the sums are composed, renders it impossible to give more than a faint idea of the enormous supplies of food required to victual the capital for a single year; but the conception may be somewhat assisted by varying the process.

"If we fix upon Hyde Park as our exhibition ground, and pile together all the barrels of beer consumed in London, they would form a thousand columns, not far short of a mile in perpendicular height. Let us imagine ourselves on the top of this tower, and we shall have a look-out worthy of the feast we are about to summon to our feet. Herefrom we might discover the great Northern road, stretching far away into the length and breadth of the land. Lo! as we look, a mighty herd of oxen, with loud bellowing, are beheld approaching from the north. For miles and miles, the mass of horns is conspicuous winding along the road, ten abreast, and even thus the last animal of the herd would be seventy-two miles away. On the other side of the Park, we see the great Western road, as far as the eye can reach, thronged with a bleating mass of wool, and the shepherd at the end of the flock (ten abreast) and the dog that is worrying the last sheep are just leaving the environs of Bristol, one hundred and twenty-one miles from our beer-

built pillar." In like manner, he describes seven and a half miles of calves, still ten abreast, and nine long miles of swine. Birds, whose superficies would form a square not much less than the whole enclosed portion of St. James's Park, or fifty-one acres, and hares and rabbits, which, if feeding 2000 a breast, would extend to at least a mile. Let us now," he adds, "pile up all the half-quartern loaves consumed in the metropolis in the year, and we shall find they form a pyramid, which measures 200 square feet at its base, and extends into the air a height of 1293 feet, or nearly three times that of St. Paul's."

5. It would be a curious subject for conjecture and speculative inquiry, what number of individuals are employed in the capture, the culture, the conveyance, and preparation of these various kinds of food, to supply to the two millions and a half of people resident in London their daily food. No organization established by any government could do it; yet in the ordinary course of trade the supply from week to week adjusts itself to the demand.

And pursuing the train of thought thus suggested a little further, we see clearly that while each individual is labouring for his own advantage, and is thinking only of his own self-interest, he is at the same time most effectually promoting the interest of all. The daily toil is carried on in subjection to a beneficent law; and above the struggle and competition of busy crowds,

> "There's a Divinity that shapes our ends,
> Rough-hew them as we will."

6. Such are the results involved in the supply of food required by the inhabitants of one great city. If we were able to cast our mental eye over a wider space—if it were possible to survey the "great globe itself," with reference to the animal creation, and its various tribes—the population of the mighty metropolis would sink into insignificance, and the human agencies there at work "pale their ineffectual fire" before the prospect that would be revealed, and the thoughts that would be awakened. Whether the creatures feed on the vegetable productions of earth and water, or whether they live

by the destruction of other animals, we learn from the simple words of the Psalmist by whom they are fed :—

"He causeth the grass to grow for the cattle, and herb for the service of man.

"The young lions roar after their prey, and seek their meat from God."

7. It is needful to bear in mind the great abundance, as well as the great variety of animal life. The subject has been glanced at in the papers 'On the Instincts of Animals,' and 'On the Uses of Animals to Man,' to which, therefore, the reader is referred. It may not, however, be out of place to give here somewhat more fully two examples, one from the higher or vertebrate animals, and one illustrative of the abundance of life in the lower or invertebrate classes. Africa is a country which is not usually associated, in popular belief, with pasturage or with great herds of ruminating animals. Yet Africa can number thirty-four species of antelopes; and the vast herds, in which one species is occasionally seen, are so well described by Gordon Cumming in his narrative of 'Five Years of a Hunter's Life in the Far Interior of South Africa,' that the facts are given in his words :—

"The accumulated masses of living creatures which the springboks exhibit on the greater migrations is utterly astounding; and any traveller witnessing it as I have, and giving a true description of what he has seen, can hardly expect to be believed, so marvellous is the scene.

"They have been well and truly compared to the wasting swarms of locusts so familiar to the traveller in this land of wonders. Like them they consume every green thing in their course, laying waste vast districts in a few hours, and ruining in a single night the fruits of the farmer's toil." In another place, speaking on the same subject, he says,—

"This was, I think, the most extraordinary and striking scene, as connected with beasts of the chase that I have ever beheld. For about two hours before the day dawned, I had been lying awake in my waggon, listening to the grunting of the bucks within two hundred yards of me, imagining that some large herd of springboks was feeding beside my camp; but on my rising when it was clear, and looking about me, I beheld the ground

to the northward of my camp actually covered with a dense living mass of springboks, marching slowly and steadily along, extending from an opening in a long range of hills, on the west, through which they continued pouring like the flood of some great river, to a ridge about a mile to the north-east, over which they disappeared. The breadth of the ground they covered might have been somewhere about half-a-mile. I stood upon the fore chest of my waggon for nearly two hours, lost in wonder at the novel and wonderful scene which was passing before me, and had some difficulty in convincing myself that it was reality which I beheld, and not the wild and exaggerated picture of a hunter's dream. During this time their vast legions continued streaming through the neck in the hills in one unbroken, compact phalanx." And again,—

"Vast and surprising as was the herd of springboks which I had that morning witnessed, it was infinitely surpassed by what I beheld on the march from my vley to Old Sweirs's camp, for on our clearing the low range of hills through which the springboks had been pouring, I beheld the boundless plains, and even the hill sides which stretched away on every side of me, thickly covered, not with 'herds,' but with 'one vast herd' of springboks; far as the eye would strain, the landscape was alive with them, until they softened down into a dim red mass of living creatures."

8. Let me now transport the reader from the hot sun and widespread plains of Africa, to the cold inhospitable region of Terra del Fuego, and direct his attention to the abundance of life, not on the land, but in the sea. Those who are not naturalists will probably think it is to fishes I am about to refer; but the fact is, that fishes, vast as are their shoals, constitute, numerically speaking, but a small portion of the inhabitants of the sea. I refer principally to animals of lower organization; but I likewise wish to show how one tribe of animals depends for its support upon another, and how if one great seaweed which grows luxuriantly on those bleak coasts were annihilated, whole orders of animated beings would perish. In this case I shall use the words of Mr. Darwin, whose

journal is a very treasure-house of valuable facts, most pleasingly narrated:—

"In all parts of the world a rocky and partially-protected shore perhaps supports, in a given space, a greater number of individual animals than any other station. There is one marine production which from its importance is worthy of a particular history. It is the kelp, or *Macrocystis pyrifera*. This plant grows on every rock from low-water mark, to a great depth, both on the outer coast and within the channels.

"The numbers of living creatures of all orders, whose existence intimately depends on the kelp is wonderful. A great volume might be written describing the inhabitants of one of these beds of sea-weeds. Almost all the leaves, excepting those that float on the surface, are so thickly incrusted with corallines as to be of a white colour. We find exquisitely-delicate structures, some inhabited by hydra-like polypi, others by more organised kinds, and beautiful compound ascidia. On the leaves, also, various patelliform shells, trochi, uncovered molluscs, and some bivalves, are attached. Innumerable crustacea frequent every part of the plant. On shaking the great entangled roots a pile of small fish, beautiful holuthuriæ, planariæ, and crawling nereidons—animals of a multitude of forms—all fall out together. Often as I recurred to a branch of the kelp I never failed to discover animals of new and curious structures. I can only compare these great aquatic forests of the southern hemisphere with the terrestrial ones in the intertropical regions. Yet if in any country a forest was destroyed, I do not believe nearly so many species of animals would perish as would from the destruction of the kelp.

"Amidst the leaves of this plant numerous species of fish live, which nowhere else could find food and shelter; with their destruction the many cormorants and other fishing birds, the otters, seals, and porpoises, would soon perish also; and lastly, the Fuegian savage, the miserable lord of this miserable land, would redouble his cannibal feasts, decrease in numbers, and perhaps cease to exist."

9. Let not any one for a moment suppose that it is needful to go to another hemisphere for examples of the abundance of animal life. Look into one of those lovely little rock pools abundant round our own shores, and you will find multitudes of creatures enjoying the happiness of existence. Some of them, sporting among the *confervæ* and *corallines* which fringe the sides of the pools, seem like sportive beings enjoying themselves in the midst of a miniature forest. And so great is the variety of these tiny beings that they belong not only to different Orders, but even to different Classes, of the animal kingdom. And if you extend your survey a little further, you will see in many parts every rock covered with acorn shells of diminutive size; and in the deeper water, where the large fronds of the tangle gracefully rise and fall with the ocean swell, you will occasionally find their surfaces covered with the cells of polypes, whose numbers are to be estimated, not by thousands, but by hundreds of thousands; reaching, in some instances, even to millions.

10. This part of my subject cannot be more appropriately concluded, than by a quotation from Humboldt. "When the active spirit of man is directed to the investigation of nature, or when in imagination he scans the vast fields of organic creation, among the varied emotions excited in his mind there is none more profound or vivid than that awakened by the universal profusion of life. Everywhere, even near the ice-bound poles, the air resounds with the song of birds and with the busy hum of insects. Not only the lower strata, in which the denser vapours float, but also the higher and ethereal regions of the air, teem with animal life. Whenever the lofty crests of the Peruvian Cordilleras, or the summit of Mont Blanc, south of Lake Leman, have been ascended, living creatures have been found even in these solitudes." The same eloquent author also states: "The condor, that giant among the vultures, often soared above us at a greater altitude than the summit of the Andes, and even higher than would be the peak of Teneriffe, were it piled on the snow-crowned summits of the Pyrenees."

The mind of the reader will now be familiarised with

the idea that in every quarter of the globe, in the arctic seas as well as in the tropical forests, life, vigorous and abounding life, presents itself: and this fact necessarily implies another, namely, that the food, whether vegetable or animal, required by each tribe of animals, is bountifully supplied for its support.

LESSON II.

MEANS OF PROCURING FOOD.

"The eyes of all wait upon Thee; and Thou givest them their meat in due season."

1. We shall find that the kind of food suitable for each animal, is not merely adapted to its internal organization, but exercises, if we may so express ourselves, an important and modifying influence on all its habits. Some creatures, of low organization, live surrounded by the fluids which supply them with nutriment; they have neither the emotions of fear nor the cravings of hunger to rouse them to exertion, and they pass their existence duller

"Than the fat weed that rots itself in ease on Lethe's wharf."

2. Many of the herbivorous quadrupeds find pasture and repose on grassy plains or in fertile valleys; and except in those cases where they migrate in vast herds, their active powers undergo but little development. In some among them, however, that are exposed to vigorous and formidable assailants, we find acuteness of the senses, and other appliances furnished, so as to warn them of danger, and supply them with the means of escape. The truly predaceous animals, prompted by the calls of hunger to wage war on other living creatures, exert to the utmost their powers both bodily and mental. The cravings of appetite are to them stimulants to additional exertion: where the ox or the horse would lie down and die of lack of nourishment, the wolf or the tiger would be roused to put forth all his strength, and bring every faculty into action.

3. The habits of animals, and the nature of their food, must therefore be considered together. The subject is too comprehensive for a brief treatise such as this; but matter for profitable reflection may be brought forward,

if we consider, however slightly, the diversified organs by which food is procured. Some of these organs are pumps and syphons for the conveyance of fluid nutriment; some are prehensile organs for the capture of living prey, or the conveyance of food, whether animal or vegetable, to the mouth; some again form a masticating apparatus for the conversion of the food into a state suitable for its being received into the stomach, and there digested.

4. If among animals dwelling on the land, we take those which are found at the highest elevations, they will probably be the condor of Chimboraza, and the lammergeyer of the Alps. They both exhibit, like the eagle of our own mountains, a structure of the beak and talons, admirably adapted for seizing and tearing up their prey. The lion of Africa, and the tiger of Bengal, manifest an adaptation of structure not less admirable, viewed in reference to their habits. They are too well known to require to be dwelt upon; the naturalist and the anatomist have alike expressed their admiration of the apparatus employed, and the means by which it is worked.

5. The largest quadruped is furnished with an organ which, in regard to the variety of purposes to which it can be applied, excels perhaps all other prehensile organs, except only the human hand. I allude of course to the proboscis of the elephant. Furnished with thousands of muscular fibres, arranged longitudinally, transversely, and diagonally, it possesses unrivalled flexibility, and can act with precision and delicacy, or with tremendous power. The steam-hammer of Nasmyth can be brought down so gently as to close the lid of a snuff-box, or so forcibly as to destroy the coherence of a block of timber, and convert it into a mass of woody fibres. So the trunk of the elephant may gently pluck a flower or may uproot a palm-tree. It acts not only as a nose, but as a drinking-cup; as a bellows and as a syringe. The elephant, in its native forests, breaks off by means of its trunk the branches on which it feeds; its enormous teeth, like powerful crushing mills, triturate the mass, and as they become

worn away are replaced by others, developed in due succession. Thus gifted with strength, and with organs of exquisite structure, the "half-reasoning elephant" lives, "hostile to none, of none afraid."

6. Many animals use their paws as prehensile organs for seizing their food and conveying it to their mouths. The squirrel and the monkey are familiar examples. The spider-monkeys of the New World have long tails which they curl in an instant round the arm of a tree, and can thus be supported in their gambols or their labours, when their paws are otherwise engaged. These tails, however, perform another office; they are actually employed in the conveyance of food. The end of the tail is destitute of hair, has a sensitive skin, and can seize any small object. These monkeys enjoy with much zest the delicacies which the American forests afford, such as fruits, eggs, and young birds. While engaged in explorations for such dainties, they are said to introduce the tail as a feeler into the fissures of trees, and by this singular instrument hook out eggs or other substances.

7. We have glanced at the talons of the eagle, the claws of the tiger, the proboscis of the elephant, and the tail of a monkey, as organs of prehension. The tongue, variously modified, acts also as a prehensile organ. By it the giraffe can seize as food the branches of trees; by it the ant-eater can revel on the food from which it derives its name. The tongue of this creature is long and slender, bearing some resemblance to an earth-worm. When laid on the ground in the tract of the ants, it is soon covered with them, and is then quickly retracted. The insects are swallowed without mastication; teeth would have been superfluous, and the ant-eater is therefore destitute of them.

Among the reptile tribes, the modes of capturing food are as different as a frog, a snake, a lizard, or a tortoise, the representatives of the four groups into which this class is divided.

8. Among fishes, there are extreme modifications both in the structure of the mouth, and the dental apparatus with which it is provided. In the shark, whose teeth

are subject to injury by the struggles of its prey, there is abundant provision for a supply of those formidable weapons. Some rapacious fishes swim near the bottom, and there seize on their food. Others remain stationary and await its coming. It is thus that the fishing-frog, like a patient angler, lures his victims to approach; it is thus that a strange and ugly fish, the *uranoscopus*, of the Ægean sea, lies with its body buried in the sand, its bright eyes sparkling like gems, and seizes its unsuspecting prey when passing above.

The powerful electric battery with which the torpedo and the electric eel are provided, is not only a means of defence, but a formidable array of artillery for stunning and disabling their prey. One little fish of brilliant colours (*Chætodon rostratus*), whose food consists principally of flies and other insects, adopts a projectile well suited for "such small deer;" it shoots them with a drop of water!

9. Among the various orders of insects there prevails a great variety of food, and a corresponding variety in the parts which constitute the mouth. When liquid food is to be conveyed, we find in the butterfly a double tube; in the gnat, lancets, which pierce the skin and form a tube for suction; and in the bee, a proboscis, admirably fitted for collecting the nectar of flowers. When solid food is required we find formidable trenchant instruments in the carnivorous beetle, the rapid dragon-fly, and the well-known locust. So full of wonder is the history of these creatures, that the tale of the naturalist is scarcely inferior in marvel to the story told by that worthy old traveller, Sir John Maundevile, of ants the size of hounds keeping guard over hills of gold:—"In the Yle also of this Taprobane, ben grete Hilles of Gold, that Pissemyres kepen fulle diligently. And thei fynen the pured Gold, and casten away the unpured. And theise Pissemyres ben grete as Houndes: so that no man dar come to the Hilles: for the Pissemyres wolde assaylen hem and devouren hem anon."

10. If we turn to invertebrate animals inhabiting the sea, we find there some that observe a strictly vegetable diet, and others that are carnivorous, furnished according

to their wants with a tongue that can rasp the sea-weed, and so reduce it to a pulp: or that can act as an auger, and so pierce the shelly covering of their victims. Those who have never examined the tongue or lingual ribbon of these humble mollusks, would find them most attractive objects for examination under the microscope. In each genus the form of the teeth, the number, and the arrangement is different. The common limpet of our coasts exhibits nearly two thousand siliceous teeth, an allowance which is moderate compared with that of some other mollusks. But let the number or "pattern" of the teeth be what it may, one fact is obvious, that the tongue of one of these humble creatures is an instrument for the prehension or the preparation of its food, not less perfect "after its kind" than the proboscis of the elephant. It speaks of a perfection which only the works of God can manifest: it tells of a care for the lowest of his creatures which He only can exert, whose fiat called them into existence, and whose Providence gives to them "their meat in due season."

11. Among the "shell-fish" on our coasts are many families, such as the mussel, the oyster, and the scallop, which do not move about in quest of food, but have the power, by means of minute hair-like bodies termed *cilia*, of producing currents in the water, and thus bringing to their mouths the nutritive particles on which they subsist. The stomachs of such animals are store-houses of *infusoria*: many of these minute siliceous or ganisms, taken from such a depository and "mounted" for the microscope, become permanent examples of the exquisite beauty which pervades even the very lowest forms of organized existence.

The mollusks which in point of structure hold the highest rank, are the *Cephalopoda*, or cuttle-fishes. They possess eight or ten muscular, flexible arms, on each of which is a number of suckers of most admirable mechanism. Once these suckers touch the prey, escape is impossible, the arms close round the struggling victim, and the horny parrot-shaped beak tears up the flesh or breaks the shell. So great is the force with

which the arms of the cuttle-fish adhere to bodies by means of this apparatus, that "while the muscular fibres continue contracted, it is easier to tear away the substance of the limb, than to release it from its attachments."

In the sea-urchin and the star-fish we see hundreds of tubular suckers, sufficient to seize and overpower any unfortunate crab or periwinkle which may come in their way; while at the same time no "dainty dish" of decaying animal tissue is rejected.

12. The star-fish and the sea-urchin have a tolerably strong integument or covering; we are prepared therefore to expect that any prehensile apparatus they possess may be brought into play with considerable power. Such an integument is wanting in the gelatinous creatures, known as sea-jellies or nettle-fishes; yet they have, in the long contractile filaments possessed by some species, a most effective apparatus for stinging; and in the arms an efficient means of grasping their prey. The apparent fragility of their own bodies, and their power of destroying those of others which appear well protected against such attacks, seem so contradictory that we require to have the fact upon undoubted authority. I shall quote, therefore, the words of the lamented Professor Edward Forbes; he is speaking of a medusa, less than half an inch long, the *Sarsia tabulosa*, a species found at times rather plentifully on some parts of the coast:—"Being kept in a jar of salt-water with small crustacea, they devoured these animals, so much more highly organized than themselves, voraciously, apparently enjoying the destruction of the unfortunate members of the upper classes, with a truly democratic relish. One of them even attacked and commenced the swallowing of a *Lizzia octopunctata* quite as good a medusa as itself. An animal which can pout out its mouth twice the length of its body, and stretch its stomach to corresponding dimensions, must indeed be 'a triton among the minnows,' and a very terrific one too; yet is this ferocious creature one of the most delicate and graceful of the inhabitants of the ocean—a very model of tenderness and elegance."

13. It is time this chapter were drawing to a close: entire orders of animals, such as the crustacea, the entozoa, the zoophytes, and the whole range of microscopic life, remain unnoticed; but enoughhas been told to show the extent of animal life, the providential care by which it is supported, and the wondrous yet diversified organs with which different tribes of beings are provided in order to procure that sustenance on which their existence depends. It must be recollected too, that in many cases these organs vary with the advancing maturity of the animal. The caterpillar, which devours the leaf, in a few weeks has lost its cutting jaws, and has a tube for imbibing honey. Some animals, such as the *Cirrepeda*, or barnacle and acorn shells, are free in the early stages of life, but become fixed to one spot at a later period, and of course adopt a different mode of obtaining nourishment in these altered circumstances. There are other animals which reverse to some extent this process —which are fixed like minute sea-weeds when young, and swim about freely in their more advanced condition. Of this we have an example in the rosy feather-star (*Comatula rosacea*) of our own shores. In an early stage it looks like a tiny plant; it swims about, with five pair of graceful arms, when more mature. Let me reward the juvenile readers who have borne me company thus far, by presenting them with some of the facts of science in the guise of a fairy tale. To works professedly treating of zoology, I must refer them for fuller information respecting the *crinoid*, or lily-like star-fishes, which have given origin to those perforated fossils, known in the north of England as "St. Cuthbert's beads," and to which reference is made in the following

Fairy Tale.

"Once upon a time there grew beneath the waters of the sea a delicate-looking little plant. It had a spreading base, and a stem, surmounted by many branches; yet so tiny were its dimensions, that the piece of gold which mortals call a 'sovereign,' would be sufficient to cover half-a-dozen such miniature trees. There it grew, surrounded by the strange and varied forms that deck

the ocean bed, and visited by divers creatures that crept or swam at pleasure. Here the noise of the tempest never penetrated, and the sea at that region of depth was at all seasons calm as a sleeping infant. Yet the little tree was not content. It longed to see those wonders of which it had only heard. It wished to rise to the surface, and feel the rippling breeze as it passed along, and to know from its own experience what was meant by 'tossing billows.' It had heard from a communicative beroë, of the glories of a summer sky, and a diminutive jelly-fish had told of the starry splendour of an autumn night. A star-fish had given origin to a rumour that there was a limit to the waters of the ocean; and a crab, who had been a great traveller, asserted, that he had walked upon the place where the sea ended, and what he called 'land' began; but this was set down on all hands as a traveller's story. The discontent of the little tree increased; and we all know that this is a feeling which 'grows by what it feeds on.' It sought out information about its predecessors, and the collateral branches of its family; but what it learned rather increased its dejection, for it discovered that some ancient members of the family had been giants, compared with its own diminutive proportions. This went on for some time, until one of those beneficent sea-nymphs, that had not then forsaken the waters of our globe, asked it so kindly what were its troubles, that the little tree made a frank and full confession of them all. 'I cannot,' said the compassionate nymph, 'cause your root to loosen, and bid you and your posterity be free; neither can I restore to you the stature that other members of your race enjoyed in an earlier period of this earth's history; but what lies within the compass of my power shall be done. I shall remove from your stem the spreading head with all its arms uninjured. I shall endow it with new life, and give it new powers of motion, so that it may rise to meet the upper air, swim where it listeth, and even visit the boundary of the sea, though perilous it is to do so. I give to you power of growth, that your arms may increase to fifty times their present size. These gifts shall be continued to your offspring; but each of them

must, like yourself, pass the early stages of its life fixed to one spot, and present the same tree-like aspect that yourself exhibit.' The nymph smote with her wand the upper part of the stem; it broke off—ten boughs, suddenly gifted with power and flexibility, became converted into arms; the head of the little tree changed into a swimming animal, and went on its way rejoicing. Its progeny, to this day, assume at first the plant-like appearance of their parents, and at a certain state of maturity are changed, like it, into free and independent creatures."

R. PATTERSON.

Political and Domestic Economy.

LESSON I.

INDUSTRIAL SOCIETIES.

BY R. H. WALSH.

"Every kingdom divided against itself is brought to desolation; and every city or house divided against itself shall not stand."

1. PRINCIPLE OF CO-OPERATION.—When the old man in the fable, at the point of death, desired, before leaving his children for ever, to teach them impressively the benefits of union, he pointed to a bundle of sticks tied up together, and told them to try and break it. Each in succession having made the attempt and failed, he then bid them separate the sticks and repeat their efforts. They did so, and succeeded with the utmost facility in breaking the entire bundle. This little story aptly illustrates the power of men, when united, to resist evils and overcome difficulties which, if each of our race attempted to deal with separately, would be enough to occasion the destruction of all, or at least reduce us to such a lamentable condition that existence would be deprived of everything that renders it agreeable. In one point of view, this subject has already been considered, and we have shown how, when human beings mutually assist in the attainment of the general welfare, their superior ability to provide themselves with the comforts and necessaries of life, compared with what

they could do if each one attempted separately to produce and obtain whatever he wanted, is exhibited at once by a comparison between the condition of civilized men and savages. The savage endeavours, as well as he can, unaided, to build his own hut, make implements for the chase, and provide himself with such food as he can find or catch; and his inferiority in extracting the means of subsistence from the natural resources around him, when contrasted with the results arrived at, by his civilized brethen, is like the weakness of each separate stick in the bundle, compared with the strength of the entire.

2. But this mutual assistance, or "co-operation," afforded by the different trades and professions, which make up together one civilized society, is unlike that we are now about to consider, inasmuch as it is unintentional on the part of its promoters, and not the result of their design. The united efforts of farmers, manufacturers, bakers, butchers, clothiers, magistrates, police, and others, provide, as well as can be managed, food, raiment, relief from sickness, and protection for all. Yet each individual does not adopt any one of these callings *for the purpose* of assisting in the great work of which his is but a particular department. He thinks but of success in his own pursuit, and not of the results to be arrived at jointly by him and all the rest of the community, in providing for the general welfare. But when a number of persons contribute from their fortunes, the means of accomplishing some industrial undertaking, such as the construction of a railway, they co-operate *intentionally* in the object they are instrumental in effecting, by means of their mutual assistance; and each aims at the general success of the enterprise, instead of being wholly absorbed in that proportion of it which represents his interest in the concern. In fact, it is a species of instinct peculiar to man, whenever he has not sunk into the degraded condition of the savage, which occasions what may be termed social co-operation, and not any hope or perception of benefits to be thence derived; while with respect to industrial co-operation of the kind we are considering, the reverse holds good, men adopting it from a calculation of the gains they expect thereby to acquire

3. There is another point of difference between these two kinds of co-operation, which claims our attention, and it is, that while the former is universally beneficial, as appears at once from a comparison between the physical and moral condition of savages and civilized beings, the latter is sometimes positively injurious. It may be that persons unite for an object that the ordinary means of any one are quite equal to effecting, and when such is the case, co-operation is but a waste of power, and a loss to the community. Or it may be that the object aimed at is to be condemned, or, at least, not to be desired; and if it be so, co-operation is then to be more regretted according as it is more efficient. For union is powerful for evil as well as good; when, therefore, the object is bad, in proportion to the very strength its promoters derive from the mutual assistance they afford, so also in the mischief they contribute to effect by its exercise.

4. From the preceding we learn the practical importance which attends investigations relating to industrial co-operation. It is a power which may be turned to the best or the worst account; and we must accordingly feel interest in examining the circumstances under which the results are beneficial or otherwise. It is also a power fully under the control of those who exercise it, the free will of man and not his instinct leading to its adoption; so that, besides being interested in the effects which flow from it, we must likewise be influenced by the consciousness that when we know the consequences which ensue from each line of conduct, we are enabled to determine which we will have, by selecting what we perceive will produce them; while we know the evils which may ensue, we are also aware of the causes which produce them, and may select or reject them according as their consequences must be salutary or the reverse.

5. Use of Industrial Societies.—There are many works of general utility which the fortune of any single individual is rarely sufficient to completely carry on, while a number of persons, by contributing but a portion of their means, can achieve it with ease. The benefits conferred on the country by banks, insur-

ance offices, gas and water companies, railways, canals, and the like, are so great as to be really incalculable. Yet we should remain without them, or at least enjoy them to a very limited extent, were we to trust to being supplied by private individuals in the same way as we are provided with food and clothing, and indeed most other things we want. There are some exceptions, it is true, to the general rule, but they are so few as to be comparatively unimportant. The Duke of Bridgewater, for instance, invested his fortune in the construction of the canal which bears his name; and there are some banks still in existence, supported by the well-known credit of one or two individuals. These, however, must be looked on as exceptional cases only, the number of persons rich enough to act in such a manner being extremely trifling, and that of those with the necessary energy, ability, and inclination yet more so. Accordingly we perceive that if men did not join their means together for such purposes, the useful establishments and institutions referred to, would be in operation to a very trifling extent, and the country but ill-provided with the extremely beneficial services they now render.

6. Some of the undertakings we have been considering cannot be carried on except on a large scale, and, if the means for doing so be absent, will usually not be attempted at all. Canals and railways are instances of works of this nature. But others can be effected on a small scale; and the consequence of their being abandoned to the care of private individuals is not, as in the former case, that they will be neglected, but rather that they will be conducted in an unsatisfactory manner. Until recently it was not allowed in England to set up a bank with more than six partners; and the result of the prohibition was, not to leave the country without enough of banks, but to encourage the formation of such as were of a very unsafe description, and often entailed much loss on those who had any dealings with them. To support all the liabilities a bank is exposed to, a very large amount of money is required; and as it seldom happens that so much can be raised or secured, unless by a considerable number of persons, failures are common in case

of banks supported by the wealth and credit of a few. Such establishments, in consequence, are rarely countenanced to a great extent, except when some prohibition like that in question leaves no choice but between adopting them in spite of their inferiority, or else remaining without any whatsoever. In Scotland, to which the prohibition did not extend, banking has always been carried on by partnerships or associations composed of very many persons; and now in England, since the former restriction has been removed, the business is gradually getting into the hands of similar bodies. The effect of this will doubtless be to render the trade of banking in England as safe and profitable to those who conduct it, and to the public in general, as it has been for many years in Scotland, where the same cause never existed to give rise to a vicious system.

7. Misapplication of the Principle.—We have seen, that when one person cannot conduct an undertaking, or, at least, can do so but badly, it should devolve on many. A number of persons when so united are generally termed a Joint-Stock Company, or more shortly, a company; and it is worth observing that it is only in the two cases just cited, that these Joint-Stock Companies are beneficial to the public. It may be thought that, although a single individual is capable of managing and supporting an industrial enterprise, there is no reason for concluding that a company may not do so as well, or better. Such, however, is found not to be the case, the fact being, that when the individual can succeed at all, he will be much more efficient than any company. The principal reason is, that he superintends or performs every part of the business, has the strongest possible interest in its success, and can act as he likes, promptly and decisively, without being obliged to wait for the instructions of others. The company, on the other hand, must leave much of its business under the control of servants and officials, who cannot feel the same interest in the success of the establishment as the owner would, and do not, therefore, exert as much zeal, care, and energy, in the task. All the members (commonly called "shareholders") of the

company cannot for the most part constantly superintend the working of the establishment; and even if they did, they would not be as zealous in promoting its success as any one of them would be if the whole belonged to him. Each shareholder has generally many matters to attend to, besides the company he is connected with, and accordingly he gives it but little of his time and labour. The usual course is to select a few of their body as "directors," and leave most of the business to them; and these again delegate most of their authority to paid officials and servants. The magic power of the "master's eye" is little felt under these circumstances, and, accordingly, it is no matter for astonishment that when private enterprises can be successful, competition on the part of Joint-Stock Companies must be hopeless, and be productive of loss to the shareholders.

8. This salutary truth is often lost sight of, and projects without end spring up at times for effecting every conceivable object, by means of Joint-Stock Companies. They have been established for selling milk, cultivating or reclaiming land, catching fish, and many purposes beside; which every-day experience shows us that milkmen, farmers, fishermen, and others, are quite capable of doing by themselves in the ordinary manner, and which, when attempted by companies, merely result in loss and disappointment. From some returns lately published, it appears that nearly 4000 Joint-Stock Companies were in existence during some part or other of the period elapsing from 1844 to 1850, while less than 400 remained at the end. And of those which remained, nearly all were of the kind which carry on those descriptions of business unsuited, on the grounds already stated, for private individuals; while those which failed belonged almost exclusively to the class which any single person of ordinary skill and fortune, is quite capable of conducting successfully. And were the history of these companies to be followed out to their termination, we might safely conclude, judging from the past, that the few Joint-Stock Companies which still carried on the class of business adapted for private individuals, would struggle on but for a few years and then cease to exist.

9. COMBINATIONS.—Instead of uniting for the purpose of acquiring gain fairly and legitimately, by producing what is worth being paid for, people sometimes attempt to better their condition by interfering with others, in order to prevent competition in the business they themselves pursue, hoping thereby to be enabled to secure a higher rate of remuneration than otherwise they could obtain. Here we have, an instance of the way in which *the strength of union may be turned to a bad account;* for it is in proportion to its very efficiency in effecting the object aimed at—the exclusion of competition—that its effects are mischievous. This will plainly appear if we consider the case of a combination among the workmen of any particular trade, and trace the results which naturally flow from it. All combinations, it is true, are not alike, and there are movements which may be stigmatised under that name, though wholly undeserving of the reproach which it conveys in the usual acceptation of the term. But, in general, they present the objectionable features which appear in the following description. The object of the workmen is to protect themselves from the competition, either of strangers, or of the more industrious and energetic of their fellow-labourers; and to succeed in this, they endeavour to restrict the number of those who enter the trade, and prevent any of those who already belong to it from doing more than a certain limited amount of work. Various devices are resorted to, and rules enacted to secure these ends; and, in order to insure obedience, they have often recourse to much cruelty and violence, injuring and maltreating such of the workmen as refuse to do their bidding, and sometimes destroying their employers' property, or even attacking them personally in case they attempt to resist the combination.

10. STRIKES.—Having thus, as they hope, secured the field to themselves, and brought all those under complete subjection whom they allow to work, if then, the employers refuse to pay what they ask for, they "strike," as it is called—that is, they refuse to work any more until their demands are conceded. It is quite fair for any one to refuse to work for another, unless he is paid

whatever he thinks he is entitled to; but what is objectionable in strikes is, that the workmen who are chiefly instrumental in getting them up, endeavour to prevent the employers from engaging those who are perfectly willing to labour for the wages offered. If, in spite of the combination, they fail in dictating terms both to masters and men, the only result of the attempt is the loss of the time and money expended in seeking to carry it out, and the bad feeling and discord which spring up during the contest. But if, by the strength of union they succeed for a time in the object of their ambition, the chances are they will destroy the trade they belong to, by preventing the employers from satisfying the demands of their customers. These may sometimes want to buy a great deal more than usual; and if the stocks on hand be not sufficient to furnish the supplies required, the only way of meeting the extra demand is by increased production. But, to effect this, either new hands must be got in, or the workmen habitually employed must do a greater quantity of work; and as the leaders of the combination refuse to allow such expedients, the extra work cannot be done. This induces purchasers to go elsewhere; and if at length the men grow more reasonable when they perceive the bad effects of their conduct, it may be their repentance comes too late.

11. This fact deserves all the attention of the labouring classes of the present day, since, owing to the facilities for commercial intercourse which now exist, and are perpetually increasing, there is a much greater chance of successful rivals springing up elsewhere, whenever the trade of any particular locality is interrupted. Formerly, England was principally dependent on herself exclusively for most kinds of products, and each district on the seats of industry in its immediate neighbourhood. Not only did the absence of good roads and canals, inferior shipping, and ignorance of navigation, prevent the development of trade between localities not very near one another, but, moreover, between such places as lay in different countries, an additional impediment to commerce arose from the national animosities then prevalent, which led most people to look on foreign

as enemies, and discourage in various ways all intercourse with them. Under such circumstances, a particular trade might be inactive for some time, while the men were out on "strike," or it might fail to furnish supplies as quickly as required; yet there would be no danger of the customers going to suit themselves elsewhere, as, in fact, it was impossible, or, at least extremely difficult to do so. But of late years it is otherwise. So great are the facilities for transit, that most goods can be had almost as cheap at a very great distance from their place of production as on the spot; and so considerable the diminution of jealousy and dislike of foreigners, that trade with them has been freed from most of the restrictions, which, so long as they existed, prevented that ready circulation of goods between different countries, which improvements in locomotion had at length rendered feasible.

12. Hence, if workmen of one locality decline work, their former customers cease to depend on them, and purchase articles provided in other places; and then, perhaps, when the men consent to resume or extend their labour, they discover the demand for their services seriously impaired, rivals in the meantime having sprung up at a distance, either in other parts of the country or in foreign lands. Sometimes, when the employers are wearied out by the misconduct of the workpeople, they sell whatever stock they have on hand, turn everything they possess into money, and then remove to where they hope to find labourers not equally unmanageable. Ashton and Staleybridge owe their origin to the outrages in Stockport, Blackburn, Westhangton, and the older manufacturing towns; and if combination should continue to follow capital in its new places of refuge, it will flee still further. Perhaps in the end the trade may leave the country. During the strikes which prevailed so extensively not long since, various merchants had to purchase cotton goods in Germany which otherwise would have been produced in England; and had the strikes continued onger, much of our foreign trade so lost might never ıve been recovered.

13. Socialism.—Some who call themselves friends of

the labouring classes propose that instead of leaving those engaged in each trade to settle matters between themselves and the public as well as they can, the government should come forward to their assistance, providing work and wages for artisans of every description, directing their labours, and disposing of the produce.* An experiment of this nature was tried a few years ago in France, and turned out a complete failure, serving but to alarm and embarrass the rich, and excite discontent and indignation among the poor, whose expectations it raised to an extravagant height in the first instance, and then proved incapable of realizing.

To conciliate the people, elated with their victory over the late king Louis Philippe, and determined to secure all the blessings and benefits which they foolishly believed it was in the power of any government that wished to confer on them, it was enacted that workshops should be opened for the nation at large, where each person who wished might receive employment and earn wages, whilst the State, it was supposed, could be reimbursed the necessary outlay by means of what the workmen produced. It was soon found, however, the business did not proceed satisfactorily, and that if continued all the wealth of the country would be wasted and swallowed up. Indeed, the only matter for surprise is that beings of intelligence could have expected any other result.

14. There are certain duties which all Governments must perform, and surely while there is no more common subject of censure than the wasteful and inefficient mode in which they are conducted, we ought to be slow in extending their control over matters which are managed pretty well as it is. And if we examine the reason why such duties are continued to be intrusted to Government, we find it is either because it would be dangerous to allow any who liked to undertake them, or because they are of such a nature, that, though

* This usually forms a part of the scheme of those who are called Socialists. It is very detrimental certainly, but not near so objectionable as other portions of Socialism not adverted to in these few pages.

extremely useful to be performed, they would be left undone if dependent on private individuals. The Government is permitted to manage the army and navy, not from its being able to provide and equip soldiers and sailors cheaper than private individuals, but because it would be extremely dangerous to allow all who wished to raise troops and fleets, and then sell to the public, on such terms as might be agreed upon, protection against foreign enemies. In fact, were the public left to provide themselves with protection in the same way as they do with food or clothing, they would be completely under the power of such as chose to take upon themselves the office of defending the country. Bakers and tailors and other dealers are not able to force the public to pay whatever prices they may think fit to demand for their services, and therefore there is no danger in suffering all those who desire it to set up in such occupations. But were similar freedom allowed with respect to armies and navies, those who might organize such establishments would be able to force the public to pay them whatever they wished. They would become the masters of the rest were such a state of things permitted; and this is the reason why no one class, but all collectively represented by Government, are suffered to control the army and navy. On the same principle, and not because they can perform it cheaper than others, Government provide police and magistrates for the protection of the community against its ill-disposed members.

15. And there are some departments confided to the State, not on the grounds of its being unsafe to leave them to private individuals, but because the chances are that such persons would not find it worth their while to undertake them. For example, the poorer classes require education, but many of them are unable to pay for it, and it is not safe or right they should remain uneducated. When such is the case, it is not worth while to persons who require to support themselves by teaching, to instruct the lower orders; and as those who are disposed to supply the deficiency from charitable motives have rarely the means for doing so, either the poor must be suffered to grow up in ignorance, or the State

must assist in their education. Again, the Post-office furnishes a similar example of the necessity of State interference. Were the carriage of letters not made the business of Government, private individuals or companies would find it their interest to undertake the office of distributing letters in towns and all thickly-peopled localities, and between places which kept up a great correspondence. This they could do for a moderate charge, and yet be enabled to make fair renumeration for themselves. But it is thought desirable that the benefits of postal communication should be enjoyed by those living in remote and thinly-peopled districts; and as the expense of distributing a few letters among places distant from each other cannot be repaid unless a very high charge be imposed on each letter, the result is that none except the wealthy could enjoy the convenience of the post under such circumstances, if it be not intrusted to the care of Government.

There are a number of things very desirable to be effected, yet which neither private individuals nor the State always attend to; and it may be asked, why should this ever be allowed? The reason is, the expense may be too great. The Government performs many offices which would cause considerable loss to such as undertook them, had they not the means of defraying the expense by taxing others. But were taxation rendered too heavy, the nation must be ruined. To avoid this, a selection should be made between the various remedies suggested for social evils, and such only attempted as may not press too severely on the resources of the country. It were much to be wished that the very poor and the struggling should be enabled to fare as well as their wealthy neighbours. But were the Government to provide the means, there would soon be nothing left to pay the taxes. Accordingly, we rest satisfied with the moderate amount of assistance which a poor-law can afford.

R. H. Walsh.

LESSON II.

THE CONSTRUCTION OF DWELLING-HOUSES,

VIEWED IN RELATION TO HEALTH.

BY EDWARD HALL.

1. EACH of the forms of animal life requires something in the nature of the same provision for protection and shelter from the weather, as man endeavours to procure in his habitation. One animal seeks out the crannies of the rock; another selects the appropriate materials, and builds up its dwelling—with an apparent nicety of perception of what is suited to the particular object, that leads us almost to doubt whether there be any real demarcation between the instinct of the lower order of animals and the reason of man. The bird fashions her nest, and the beaver constructs his dam, on unerring principles of architecture and engineering; whilst the bee puts into practical use the learning of the geometrician.

2. But whilst the habits of each of such forms of creation remain unaltered, the position in which man is placed is ever varying. It is so, not only because in the extent of the globe there are different circumstances of climate and available building materials, but because in the human order of animal life there are peculiar original conditions of its existence. Man is always in an artificial state, and is placed so—in the very fact of his being required to *use* the faculties which are his distinctive privilege. Whilst in physical strength or other means of defence, or in capability of endurance as regards the weather, he is inferior to many of the animals—he is provided with that which can supply those deficiencies, through the exercise of his intellectual powers upon the natural products that are everywhere laid before him.

3. The condition of man being thus constantly varied and everywhere progressive to an order of civilization still higher than that existing, the mind should be ever alive to the fact of these changes, and as ready to

supply the new wants as the lower animals are to meet the old. Yet it is remarkable that such progression in contrivance has at all times been tardily manifested in human habitations. The long endurance of inconvenient arrangements in houses, has been commented on by those who have treated of the history of domestic architecture. Similar influence of habit affects the household comfort and convenience, and the health and morals of the people, to the present hour. Further, there are circumstances of society to be mentioned, which render the importance of alterations in the arrangement and construction of dwellings, just now very great.

4. The recent Census returns have shown that 10,000,000 of people had been added to the population during the previous half-century—an increase said to be nearly equal to that of all preceding ages. The addition during the last ten years, has been 2,300,000 persons, a number exceeding the increase in the last fifty years of the eighteenth century. In London, the population, which in 1831 was 1,654,994 persons, in 1851 was 2,362,236. The general increase had taken place solely in the towns—not in the rural districts. Even in 1840 it was found that whilst in 1790 the workers in towns had been to the labourers in the country, as one to two, the proportion was then exactly reversed. The proportion of manufacturers, miners, and artizans, or of those classes requiring habitations near to one another, and therefore more especially demanding economy of space and good arrangements for convenience and health, was, to the agricultural labourers in Staffordshire, as three to one, to those in the West Riding of Yorkshire six to one, in Lancashire ten to one, and in Middlesex twelve to one.

5. With the proper application of the resources of science to new circumstances, positive advantage should result from association of numbers: but here, the growth of the population has been too rapid, and the progress of investigation too slow, for the necessities of the case. Latterly, the disproportion above discovered has been increased—especially in London, where the great value of ground, and the necessity of living within moderate d

tance of daily avocations, has produced a condition of society, even as regards those having some pretensions to education, which is dangerous to morals, costly to those who have little to spare, and destructive to health. Some of the causes of the last-mentioned result are treated of in another part of this series of lessons; but after every attention has been paid to sewerage, water supply, paving, the regulation of noxious trades, and other external sources of influence, the evils referred to may still be occasioned by the absence of proper contrivance within the walls of the habitation itself.

6. A far greater number of suggestions for improvements in houses, indeed, have been made, than we have space to point out. We might refer especially to many internal fittings and appurtenances. In London, the cause of failure is to be sought for in an earlier stage of the proceedings. It originates in a radical error, generally in the principle on which the habitations are devised. Houses are built on plans suited to the requirements of a century ago, but ill adapted to the circumstances which we find have accrued since. It is only necessary that the real condition of things should be *recognized* and met. The modified arrangements required can be readily pointed out, and, indeed, have been practically demonstrated in model-dwellings built by the metropolitan associations, and in the residences in Victoria Street, Westminster, for a superior class of inhabitants.

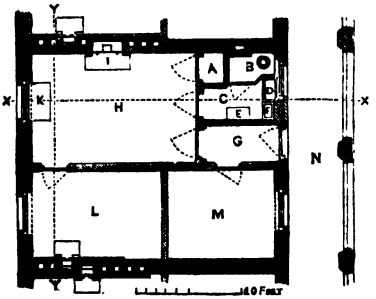
7. In the closely-populated districts, what was originally a house for a single family can no longer be so occupied. Thus, what were merely separate rooms, become distinct residences. It is clear, however, that every residence requires certain adjuncts and conveniences—as its own outer door and lobby—and for the purposes of occupation, the same distribution of parts and appurtenances, as the original house. If these essentials are not attended to, the lamentable evils endured in London are inevitable. Far from each residence there having the required adjuncts, the subdivisions of the original house, and the multiplied inhabitants, have only the conveniences of the original house. The plain results, without going far to find them, must be discomfort,

dirt, and disease. Then, the consoling influence of a true "home" is not felt—its ties become a curse rather than a blessing; and after the moral fortitude of a parent has been sorely tried, the end of a whole family is often found in intemperance and ruin.

8. It will be seen, that whether for the sake of expense, comfort, morals, or health, it is essential, not only that every residence should have the various subdivisions, as well as particular and independent provisions and building contrivances, but that these should be placed in the best relative positions. The general principle is the same, but the arrangements will alter in every case. It is part of the business of professional architects to devise such arrangements; and had their ordinary skill been called into use as might have been expected, the various social and sanitary evils referred to would hardly have been met with. It would be unsuited to the present work, to give all particulars of the changes required: but it will be seen, that were a building contrived, as large as *several* of the present houses, so that one staircase might answer in place of several staircases, great space would be gained for the better arrangement of each residence contained in the building, and for the provision to each of all the requisites of a house. This has in fact been done in several cases; and one of the results during the last visit of the cholera, was, that whilst hundreds were dying in the houses round about, none of the inhabitants of the improved residences suffered. Another proposal which we may mention, is to have external galleries and staircases to each story of a large front, so that each person's own front door would be towards the open air, instead of towards the staircase, which in the other case stands in place of the public street.

9. An examination of the cuts which are here given, with the appended references, will show what is required. They exhibit the general internal arrangement and fittings of one of the number of associated residences in Streatham Street, Bloomsbury, designed by Mr. Roberts. The illustrations consist of a plan and two sections, supposed to be taken, one at the dott

line x x on the plan, and the other at y y. There are other residences on each side in the same story, and in the stories above and below, as indicated, all being of the same character. It will be seen that the access is from an external gallery, though, in the particular instance of Streatham Street, this looks towards a private quadrangle, in place of the public street. Of course different arrangements might be necessary, according to the requirements of the particular class of tenants calculated upon in each case; but it will be seen that we have here all the conveniences of a house, and the three sleeping-rooms, which should be held as the least possible provision for family residences, wherever there is the slightest pretence to civilization.



One of the Residences in Streatham Street, Bloomsbury.—*Plan.*

Reference.

A.—Closet, opening out of living-room; may be used for boy's turn-up bedstead.

B.—Water-closet, with slate cistern overhead (shown at C in the section on x x) provided with Ridgway's glazed stone-ware soil-pan.

C.—Scullery.

D.—Slate sink.

E.—Dresser-flap, hung on hinges.

F.—Meat-safe, with slate shelves: also plate-rack.

G.—Lobby of entrance from external gallery.

H.—Living-room, the floor being of Portland cement, as in the preceding.

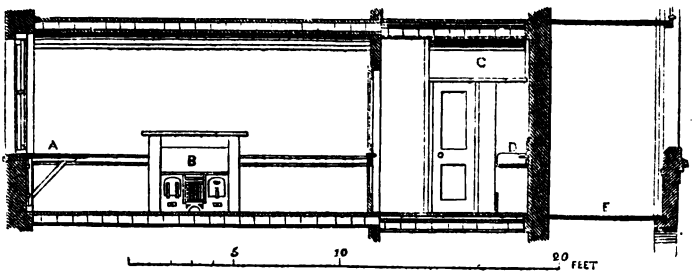
I.—Kitchen-range, with slate chimney-piece.

K.—Dresser-flap, hung to hinges: serves as half-shutter.

L.—Bedroom, with fireplace.

M.—Bedroom, without fireplace.

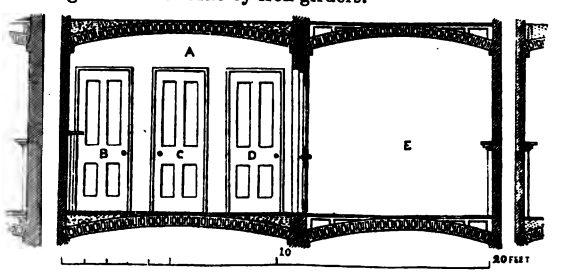
N.—External gallery, with slate floor.



Section on the Line X X on Plan.

Reference.

A.—Living-room, showing section of dresser-flap, &c.
B.—Kitchen-range.
C.—Slate cistern, to hold ninety gallons.
D.—Slate sink.
E.—External gallery,—the front carried on brick arches: the alternate galleries are borne by iron girders.



Section on the Line Y Y on Plan.

Reference.

A.—Living room.
B.—Door, opening into closet.
C.—Scullery.
D.—Lobby.
E.—The bedroom, with fireplace.

10. We must, however, not omit to speak of the general requirements in every kind of residence.—We go back to the question as to the first wants of man. One of the first was of the means of shelter from extremes of climate,—heat or cold, wind or rain. Privacy, also, was soon needed, and protection from external violence was speedily called for. Beauty

design was essential in the provision for such ends, and thus the art and science of architecture grew up.

SITE.—A site must be chosen whereon these objects may be attained, and otherwise consistent with attention to some requisites yet to be noticed. The soil should be free, or capable of being made so, from damp and noxious exhalations; and it is on that account that a gravel foundation, which allows any moisture to percolate, is preferred to clay, which is impermeable to, or in other words, retentive of water.

WATER.—The house, or site for a new one, should be selected with especial reference to a copious supply of water, both spring and soft; and in a new district, it would be well to have the water subjected to chemical analysis; for there are certain sources of impurity, even in water from wells, which are offensive, if not injurious; and, on the other hand, if certain salts in solution be absent, the water will act upon lead, and so gradually poison the inhabitants. Lead, however, as a material for water-supply pipes, will perhaps shortly be wholly disused. Iron has been substituted with advantage in many cases. The necessity, in many towns, of storing water in cisterns, which are often badly devised, is a fertile source of impurity, but will, it may be hoped, be removed in many cases, by recourse to the system of constant supply.

DRAINAGE.—There must be means adopted of getting rid of all the drainage—without the return of noxious effluvia towards the house, or indeed the detriment of neighbouring houses. The outfall, or place of final emission of sewage, the material, size, and inclination of the several drains, and the means of preventing the return of foul air into the house, are all matters for the most particular attention, and which are not the less important to health, because they are not immediately before the eye, or because they are often treated with gross negligence.

ASPECT.—If the house be in an exposed situation, it is desirable that the aspect of the windows and principal apartments, should be chosen with reference to prevailing winds and rains.

LIGHTING.—The house must be lighted by an ample

area of window opening, light being not only productive of cleanliness, but being directly advantageous to health. If artificial lighting by gas be resorted to, contrivances for getting rid of the noxious products of each burner must be introduced, or the inmates of the house will pay dearly for the omission. It is true, that all consumption of the oxygen of the air requires an immediate removal of products which are destructive to life; but where they exist, unventilated gas-burners are the most fruitful sources of inconvenience. Independent of this, —*ventilation* in ordinary houses should be attended to. Bedrooms especially require copious supplies of air frequently renewed.

11. The requisite attention is not always given to some of these objects, whether in the case of residences in towns, or of those in the country; and although the manner of effecting the ends is often matter of learned discussion, they are points to which attention should be given by some competent person on behalf of any one building or taking a house. Although it may require the special qualifications to form a tolerable opinion on such subjects, and although, where so much is concealed from the eye, mistakes may occur with the most competent judges, there are still some of these points on which we might give a few more remarks.

There is no more fertile or insidious source of injury than damp. It has been well remarked, that "death resides in a humid dwelling." Damp may be occasioned not merely by leakage in the roof and gutters, and by the nature of the site to which we have alluded, but from the very material and construction of the walls themselves, and the manner in which the work of the building had been originally performed.

In considering the course to be chosen in the selection of materials and appliances, it may be well again to review the original conditions of climate and habitations. In the early state of society elaborate contrivances were not necessary. Where a cavern or an artificial excavation could not be used, a canvas enclosure might secure privacy, and a rude hut might afford shelter. To such beginnings, styles of architecture have been traced

for example, the peculiar character of mural decoration practised by certain nations, may have originated in the hangings and the materials of the tents which were the abodes of the original pastoral people. The requirements of an itinerant race and those of residents in towns, however, are no more identical than are the dwellings which are adapted to tropical heat and Crimean winter. Still, there are general principles of disposition and construction which may be usefully considered. An enclosure and a roof are required of sufficient thickness and substance to resist sudden alternations of temperature, whether towards heat or cold. The material used should as nearly as possible be non-conductive of heat, as well as of moisture. We therefore see how hasty were some of the opinions which were popular in 1851, as to the universal application of iron and glass.

12. Some of the kinds of walls built up with clay and chopped straw, or those which are hollow, if they possessed the requisite stability, would best answer the conditions. Brick is the nearest approach to these; and the material is further recommended to the workman, by the facility of handling which there is, in the smallness of the pieces, and by the possibility of securing stability—along with the greater part of what is otherwise important—without loss of ground and the expense attendant upon very thick walls. Some kinds of building-stone are rapid conductors of heat, and therefore *on this account* would be less desirable. The rain may not pass through, but the moisture of the air within may be condensed by the cold of the walls. In bricks, the clay should, however, be better burnt than it is generally in the neighbourhood of London. In the ordinary process of manufacture, there are a large number of what are called "place-bricks," or those which could not be placed so as to receive the full heat of the fire. These are used by the speculative builders to a large extent. There is a proverb that "fools build houses, and wise men buy;" and this, like some other well-known sayings, is acted upon, though it involves a mistake. The person deceived is surely he who expects to get *necessarily* the same thing, for a less sum than he would have had to pay for

a good article. In the case of the place-bricks, the particular defects are not easily detected by inexperienced persons; and indeed in the completed house the greater part of the brickwork is concealed; and it must be admitted that the real inferiority of the house may never be discovered,—so little alive are the generality of persons to the slow but unnecessary outgoings of all kinds of expenditure, and those insidious inroads of disease, which inevitably await those who dwell in badly-built houses. However, there are often more serious defects than the mere use of "place-bricks."

13. The defects of brick walls, as executed, are more generally to be attributed to the thinness of the walls, or to insufficiency in the interlapping, or "bonding," required for the stability of work that, as we said, is made up of small pieces; but which bonding, bricklayers give insufficient attention to. As to thickness,—since a wall of nine inches, or one brick-length thick, may answer the mere purpose of stability for the height of one or two stories, it follows that in such houses as we refer to, it must be often employed. But, in exposed situations, the wet may pass *through* such a wall,—more especially, since the workman does not always completely fill the spaces between the bricks with mortar.—These several objections have been sought to be removed in various ways. Glazed bricks, or glazed tiles, as a covering, have been adopted to some extent; but the cost of these articles is not, as yet, sufficiently moderate. Many of the houses on the terrace at Brighton, much exposed to the spray from the sea, are faced with these glazed materials. Another practice is that of building the walls hollow, or like two thin walls a few inches apart. This may be made to answer the purpose, though there are difficulties in getting the bonding properly executed by the workman; for if the two thicknesses were not connected here and there across the cavity, the work would fall. To the same object of excluding damp, the different forms of hollow bricks are applicable; and where they can be procured, they deserve to be used in preference to the ordinary forms. Mr. Henry Roberts, so well known for his philanthropic

efforts to improve the dwellings of the poorer classes, has invented one arrangement of hollow bricks in which there is the requisite "bond," without the use of "headers," (or bricks which pass through the full thickness,) so that there is less chance for the wet to get through; and in thin walls of cottages, this invention must be highly commended. The more common mode of getting rid of the damp is by coating the wall with cement. This is certainly effectual, but it is the source of great expense, becomes the excuse for much bad brickwork, and is the occasion of want of attention to architectural design, and has to do with most of such inferiority as exists in general taste. If the walls were built of not less than one brick and a half length in thickness,—with the work properly executed, all objects could be answered. It is not uncommon on the inside of walls, to contrive a hollow space by means of timbers called quarters, and lath and plaster; but in such cases as we have referred to, it would be better to keep the damp from *getting into* the wall.

14. Walls which are otherwise well built, may still be subject to long-continued damp. If the bricks have been laid during very wet weather, the house may remain damp for a surprising length of time. We have known cases where brickwork laid in the autumn, has not been dry before the end of the summer in the next year. And where sand in the slightest degree impregnated with saline matter, like that from the sea-shore, has been used for mortar, or plaster, the walls will be always in a damp state. Where the ground of the foundation is not well-drained, damp even rises up the porous material of the wall. To prevent this, a layer of asphalte, or someother impermeable contrivance, is sometimes placed in the bed of one of the lower courses of brickwork, over the whole area of the walling.—There should be some vacant space below the lowest floor of the house, and this space should be well ventilated by iron "air-bricks" in the external walls. Some old houses where there is no cellar story are found very defective in this particular. Before taking such a house it would be well to notice whether the floors get dry soon after being

washed, and also in what state are the carpets and matting, and the wall-papers near to the skirting. A cellar story, even with the space under the floor, may be damp from the wetness of earth against the outer walls. Such contact may be easily prevented by placing a thin wall outside the main wall, so as to leave a narrow vacant space all round the house. The causes of damp sometimes elude detection for years, and perhaps are at last traced to a spring under the house, or to the leakage of a pipe, or some other matter whereabout neglect had taken place in the original building. Entire houses may be found uninhabitable from causes never to be discovered. These details, however, are such as would require very lengthened description.

15. The great requisite in taking a house—more especially a new one, where the character of the builder is not known—is to be alive to the fact of the really momentous nature of the task. We have noted some points in regard to which inquiry may be made, and others will suggest themselves. The house should be visited at different states of the weather, and appearances, such as we have referred to, should be looked for. The situation of the drains, and the fact of their perfect delivery of the contents from off the premises, should be known. Any offensive smell, not readily and permanently removed by pouring down a few quarts of water, should be conclusive testimony to the unhealthiness of the place. A small quantity of water in the "trap" of a drain, is required to prevent the return of effluvia, and this water, when a house has been unoccupied, may have dried up.

Many persons have dated an inroad into their constitution, permanent, though not discovered for a long interval, to a change in a place of residence. A well-constructed house, with all its defensive parts and its working machinery in order, is really a great emanation from human skill, and an humble imitation of the work of the Great Architect of the human form,—acquaintance with the *anatomy* of which has indeed been held as an essential element of knowledge for the practical designer and constructor.—E. HALL.

THE BUILDERS.

All are architects of Fate,
Working in these walls of Time;
Some with massive deeds and great,
Some with ornaments of rhyme.

Nothing useless is, or low,
Each thing in its place is best;
And what seems but idle show,
Strengthens and supports the rest.

For the structure that we raise,
Time is with materials filled;
Our to-days and yesterdays
Are the blocks with which we build.

Truly shape and fashion these,
Leave no yawning gaps between;
Think not, because no man sees,
Such things will remain unseen.

In the elder days of art,
Builders wrought with greatest care
Each minute and unseen part,
For the gods are everywhere.

Let us do our work as well,
Both the unseen and the seen;
Make the house where gods may dwell
Beautiful, entire, and clean.

Else our lives are incomplete,
Standing in these walls of time;
Broken stairways, where the feet
Stumble as they seek to climb.

Build to-day, then, strong and sure,
With a firm and ample base;
And ascending and secure
Shall to-morrow find its place.

Thus alone can we attain
To those turrets, where the eye
Sees the world as one vast plain,
And one boundless reach of sky.

LONGFELLOW.

Chemistry.

BY EDWARD FRANKLAND.

LESSON I.

NON-METALLIC ELEMENTARY BODIES.

1. The non-metallic elementary bodies, or *metalloids*, are thirteen in number, and are named as follows:—

Oxygen,	Selenium,
Hydrogen,	Phosphorus,
Nitrogen,	Chlorine,
Carbon,	Bromine,
Boron,	Iodine,
Silicon,	Fluorine.
Sulphur,	

2. The metalloids are distinguished from the metals, chiefly by their being non-conductors of heat and electricity, and by their not possessing the metallic lustre. It has, however, been already mentioned, that the three metals—arsenic, antimony, and tellurium—are intimately associated with the metalloids in their chemical relations, although in their physical properties these elements are indubitably metals; we shall therefore study them in connection with the metalloids. Thus associated with arsenic, antimony, and tellurium, the metalloids may be grouped into the following five divisions; the separate members belonging to each being characterized by a certain community of chemical character.

1st Division.—Oxygen, Sulphur, Selenium, Tellurium.

2nd Division.—Hydrogen.

3rd Division.—Nitrogen, Phosphorus, Arsenic, Antimony.

4th Division.—Chlorine, Bromine, Iodine, Fluorine.

5th Division.—Carbon, Boron, Silicon.

3. Althought his grouping is of service, in indicating the more or less close chemical resemblance of the several bodies contained in each division; yet it will be necessary, in studying the separate elements, to depart occasionally from this order of classification, and to give priority to those elements, which possess the highest importance, either from the interest attached to their

compounds, or from the extensive range of their affinities.

4. Oxygen.—This element is a colourless and invisible gas, constituting rather more than one-fifth of the bulk of the air we breathe, and forming a large part of nearly all the materials composing our globe. Eight out of every nine tons of the water of oceans, seas, rivers, and lakes, are oxygen, and fully one-third of the total weight of the solid crust of our globe is due to the same element. Oxygen is essentially necessary for the processes of respiration and ordinary combustion, and neither animal nor vegetable life can be supported, without a due supply of this gas in an uncombined state. The affinities of oxygen are so extensive and powerful that most of the other elements exist naturally in combination with it; so that the free oxygen present in the atmosphere, nearly represents that portion which has remained in excess, after the saturation of the other constituents of matter; and to this portion, thus remaining in excess, the fitness of our globe for the existence of plants and animals is in great part due.

5. Although oxygen is such an abundant constituent of matter; yet, owing to its intense affinities, it can be procured in a pure state, only from a comparatively small number of its compounds. It cannot be obtained directly from the atmosphere; because we are acquainted with no substance which is capable of removing the other constituent of air—nitrogen, with which the oxygen is mixed; but, by causing the atmospheric oxygen to combine with some substance from which it can again be easily expelled, it is not difficult to obtain, thus indirectly, oxygen from the air in a state of purity. For instance, if we expose metallic mercury to a current of air, at a temperature little short of its boiling point, it gradually absorbs oxygen, and becomes converted into peroxide of mercury; a substance which is well adapted for the preparation of oxygen in a pure state.

6. To procure oxygen gas from peroxide of mercury, a quantity of this compound should be placed in a retort (fig. 1), to the neck of which a bent tube is connected, for conveying the gas to a vessel in which it can be

collected over water. The heat of a spirit-lamp being then applied to the bulb of the retort, the peroxide of

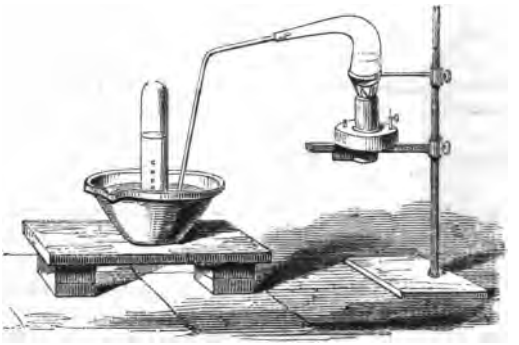


Fig. 1.

mercury is rapidly resolved into its elements, mercury and oxygen; the former condenses in the shape of brilliant metallic globules in the colder parts of the apparatus, whilst the oxygen retains its gaseous condition, and may be collected, as shown in the figure, in glass vessels previously filled with water; after a quantity of gas, at least equal in volume to the capacity of the retort, has been first allowed to escape, this first portion being contaminated with the atmospheric air contained in the apparatus. From 216 grains of peroxide of mercury, there will be obtained by this process 200 grains of metallic mercury and 16 grains of oxygen gas, which last occupies, at the ordinary temperature and pressure, about 47 cubic inches.

7. Peroxide of manganese is another metallic oxide from which this gas may be readily procured by the application of heat; but the oxygen is here combined with the metal by a more powerful affinity, so that, even at an intense red heat, a portion only of the gas can be expelled; the rest remaining behind with the manganese. The operation may be carried on in the apparatus shown in fig. 2, which consists of an earthenware retort, containing the peroxide of manganese, placed in a charcoal furnace. A glass tube connected

with the neck of the retort conducts the gas into a two-necked bottle containing a solution of caustic soda, which serves to free the gas from a little carbonic acid with which it is usually contaminated. From this bottle, the gas proceeds through another tube, to a vessel where it can be collected over water as shown in fig. 1.

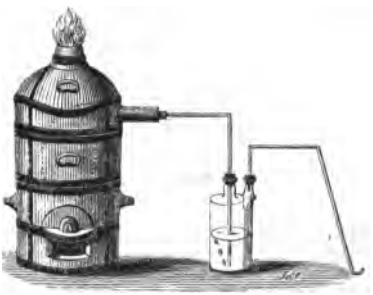


Fig. 2.

100 grains of peroxide of manganese contain 36·64 grains of oxygen; but 12·21 grains, or one-third only of this amount, are disengaged as gas, the other two-thirds remaining behind in the retort, united with the manganese.

8. The material which offers the greatest facilities for the preparation of oxygen is chlorate of potash, which consists of—

1 equivalent potassium . . .	39·00
1 equivalent chlorine	35·47
6 equivalents oxygen	48·00
	122·47

When heated somewhat beyond its fusing point, this salt is entirely resolved into chloride of potassium and oxygen gas, 100 grains yielding 39·16 grains of the gas. The decomposition of the salt is greatly facilitated by mixing it with one-third its weight of peroxide of manganese. The process may be conducted in the apparatus shown in fig. 1, the mixture of chlorate of potash and peroxide of manganese being simply substituted for peroxide of mercury in the retort. The decomposition is expressed by the following equation:

$$KO\,ClO_5 = KCl + 6.O$$

9. In addition to these methods for procuring oxygen

gas, there is another process, which, though never used for preparing it artificially, is yet of great interest, as being the mode in which this gas is produced in the laboratory of nature. The green leaves of plants possess the remarkable power of decomposing carbonic acid gas in the presence of light, assimilating the carbon and setting free the oxygen. In this way millions of cubic feet of the gas so essential to vitality are daily produced, and thus the amount of oxygen in the atmosphere is maintained constant, notwithstanding the incessant abstraction of this gas, by the processes of combustion and respiration. The experiment may be made upon a small scale, by placing some green leaves in a bell-jar filled with water, inverted in a vessel containing the same liquid, and exposing them to sunlight. The leaves will decompose the whole of the carbonic acid dissolved in the water, and give off an equal volume of oxygen, which will appear as minute bubbles on their surfaces: these bubbles gradually detach themselves and collect at the top of the jar.

10. Oxygen gas is colourless, invisible, and inodorous, like atmospheric air, than which it is, bulk for bulk, only very slightly heavier. It is dissolved by water in very small quantity. The most remarkable property of oxygen is its power of supporting combustion and respiration. All bodies which burn in atmospheric air, do so with greatly-increased brilliancy in this gas. An ignited splinter of wood, that has been blown out, continues to glow only for a few seconds in air, but immersed

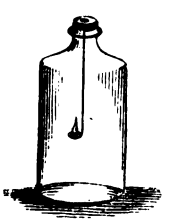


Fig. 3.

Fig. 4.

in a vessel of oxygen gas, it is immediately rekindled,

and continues to burn with a flame of great brilliancy. If a little piece of phosphorus, placed in a small metallic cup attached to a wire, be ignited and then immersed in a jar of this gas (see fig. 3), it burns with the most dazzling brilliancy. Many substances, which we are not accustomed to regard as combustibles, burn with great splendour in oxygen gas; for instance, a piece of iron or steel wire bent into the form of a corkscrew, and having a fragment of ignited German tinder placed at its lower extremity, burns with vivid scintillations in a jar of this gas (see fig. 4). If a bladder, first filled with oxygen by connecting it, as in fig. 5, with a large jar of the gas, and then depressing the jar in a vessel of water, have a jet attached to it, and the oxygen be propelled into the flame of a spirit-lamp (fig. 6), a most intense heat will be produced; steel-wire watch-springs, or small cast-iron nails, burn with intense brilliancy, and even platinum may be fused in the little jet of flame, which is much hotter than the most powerful blast furnace.

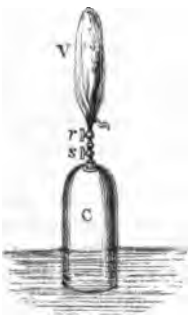


Fig. 5.

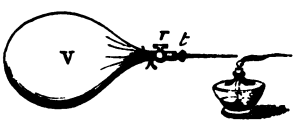


Fig. 6.

11. Oxygen gas is essential for the support of animal life: an animal dies immediately if placed in an atmosphere devoid of this gas; whilst it continues to exist very much longer in a vessel filled with pure oxygen, than when the same vessel contains only atmospheric air.

LESSON II.

HYDROGEN AND WATER.

1. HYDROGEN.—This element, like oxygen, is a colourless and invisible gas. It is very rarely met with in nature in a free state, but in combination with oxygen, it constitutes one-ninth part by weight of water, and united

with carbon and oxygen, it enters largely into the composition of all animal and vegetable substances. In a free state it is evolved from active volcanoes.

2. Water is the natural compound from which this gas is invariably prepared. Several metals have the property of decomposing water at ordinary temperatures, and setting free its hydrogen: thus a fragment of potassium thrown upon water causes such rapid decomposition, that the liberated hydrogen is instantaneously inflamed: but all the metals, which are capable of decomposing water at ordinary temperatures, are obtained with great difficulty and are consequently very expensive. Fortunately it is not necessary to have recourse to them for the artificial production of this gas, as several of the more commonly occurring metals are capable of producing the same decomposition at a red heat; for this purpose iron is generally employed, and the operation is performed in the manner shown in fig. 7: *a b* is a

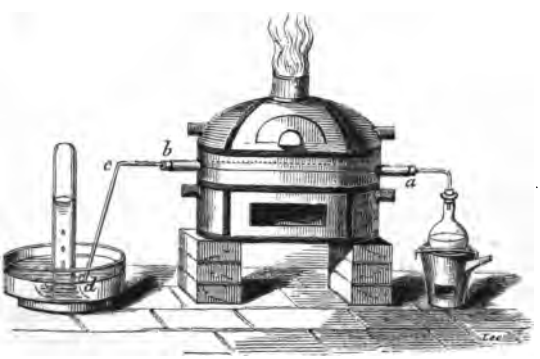


Fig. 7.

porcelain tube filled with iron filings or turnings and heated to redness in a charcoal furnace: to the extremity *a* of this tube is attached a small flask containing water, which can be made to boil by the application of a small charcoal chauffer. In its passage through the tube *a b* the steam is decomposed, its oxygen uniting with the incandescent iron, whilst hydrogen is set free and escapes at the extremity *b*, whence it is conducted by

the bent tube *c* to the pneumatic apparatus *d*, where it is collected over water.

3. Those metals, which are thus capable of decomposing water at a red heat, can also be made to produce the same decomposition at ordinary temperatures, if their affinity for oxygen be augmented, by the presence of a strong acid, such as sulphuric acid. Such a decomposition can be easily effected in the apparatus fig. 8: A is

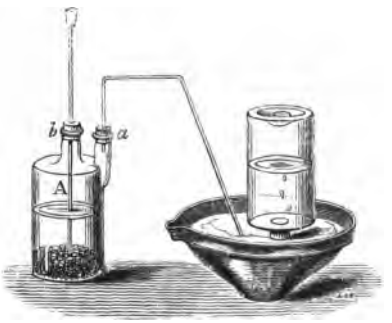


Fig. 8.

a bottle with two necks nearly half filled with water, and containing some fragments of iron or zinc. Through one of the necks *b* a funnel tube is inserted which serves for the introduction of sulphuric acid. In the other neck *a*, is placed a cork and bent tube, which conveys the gas to the pneumatic trough.

4. The apparatus being arranged, sulphuric acid is poured down the funnel tube, and the decomposition of the water immediately commences; but the gas should not be collected, until a quantity has escaped from the extremity of the bent tube equal to twice the volume of the two-necked vessel; otherwise the portion so collected would be mixed with the atmospheric air contained in the apparatus before the operation commenced, and might occasion dangerous explosions in the subsequent experiments upon the gas.

The hydrogen, prepared by either of these processes, is not completely pure, being contaminated with a minute quantity of impurity derived from the metals

employed. This slight amount of impurity imparts a peculiar odour to the gas, the properties of which are not however otherwise changed by the contamination.

5. Pure hydrogen is a colourless, transparent, inodorous, and tasteless gas, and therefore, to an ordinary observer, it is undistinguishable from atmospheric air. It is the lightest of all known matter, 16 cubic feet of this gas not weighing more than one cubic foot of oxygen, and 14½ cubic feet having only the same weight as one cubic foot of air. On this account it is eminently adapted for the inflation of balloons. If a bladder be filled with hydrogen and a tobacco-pipe attached to it, soap-bubbles may be blown and thus filled with the gas: these bubbles rise rapidly in the air, and take fire on the approach of a lighted match. Hydrogen is exceedingly combustible, but is itself incapable of supporting the combustion of a burning body. If a taper be passed up into a jar of the gas, as shown in fig. 9, the hydrogen is inflamed at the mouth of the jar where it is in contact with atmospheric air, but the taper becomes extinguished the moment it is immersed in the gas. Pure hydrogen burns with a quiet lambent, non-luminous, but intensely hot flame, when a jet of it is ignited in contact with air or oxygen as in fig. 10; but when previously mixed in certain proportions with either of these gases, its combustion takes place almost instantaneously, and is attended by a violent explosion, which is dangerous, even when the quantity of the mixed gases is small, unless the experiment be performed in a vessel of sufficient strength. If a common soda-water bottle be

Fig. 9.

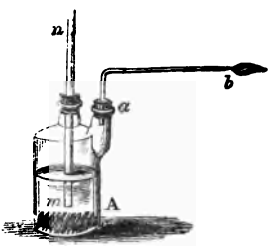


Fig. 10.

filled with a mixture of two parts by measure of hydrogen and one part of oxygen, or two volumes of hydrogen and five volumes of atmospheric air, and a lighted taper be then applied to the mouth of the bottle, the gases will explode with a loud report, which will be attended with no danger, as the vessel is of ample strength to resist the violence of the explosion. This experiment may also be very satisfactorily performed by filling a small collodion balloon with the mixed gases, and having secured its neck by a piece of thread, previously soaked in a solution of nitre and then dried, the extremity of this thread, which should be purposely left a few inches in length, should be ignited, and the balloon allowed to ascend, either in the open air, or in a lofty room. The thread gradually burns away, until the fire is communicated to the collodion envelope, when the gases explode with a deafening report.

6. The sole product of the combination of hydrogen with oxygen is always the same, viz., water; whether the union of the two elements takes place quietly or with explosive violence. This production of water by the combustion of hydrogen may be conveniently shown, by the arrangement of apparatus seen in fig. 11; where the

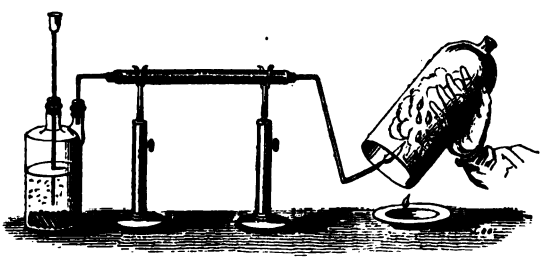


Fig. 11.

gas, from the two-necked bottle before described, is dried, by passing through a horizontal tube filled with fragments of chloride of calcium, and then ignited at the extremity of a smaller bent tube. If a bell-jar be held over the jet of flame thus produced, the glass will

soon become bedewed with moisture, which will trickle down its interior and may be received in a suitable vessel. This liquid will be found on examination to be pure water.

Hydrogen gas is incapable of supporting animal life; but when mixed with air, it may be inhaled without any deleterious effects. It is therefore not poisonous.

7. COMBINATIONS OF OXYGEN AND HYDROGEN.—Two combinations of oxygen and hydrogen are known to chemists, viz., a protoxide and a binoxide; but, as the latter is of comparatively little importance, we shall consider only the former.

8. PROTOXIDE OF HYDROGEN, OR WATER.—This highly important compound is produced, as already described, by the combustion of hydrogen in atmospheric air or in oxygen gas. It consists of one part by weight of hydrogen and eight parts of oxygen, or two volumes of hydrogen and one volume of oxygen. In nature, water is rarely met with perfectly pure. Rain, hail, and snow, collected at a distance from towns are nearly pure water; but even they contain small quantities of atmospheric air, ammonia, and organic matters, which have been dissolved by the water in its descent through the air. The water of rivers and springs is still more impure, for it is derived from rain water, which has filtered, to a greater or less extent, through the earth's strata, and has dissolved various soluble substances, some of which, such as the salts of lime and magnesia, give to it the property of *hardness*, that is, the power of decomposing soap, with the formation of an insoluble curd. Such water always leaves a solid residue when it is evaporated to dryness; the principal impurities being thus left behind, whilst pure water evaporates. Upon this circumstance is founded the method invariably adopted for preparing pure water in considerable quantity by distillation. The flask A (fig. 12) is half filled with ordinary spring or river water, and placed upon a charcoal chauffer; its neck is connected by means of a perforated cork, with the glass tube *a b c*, which passes water-tight through a larger tube of tin or zinc D E, its extremity *c* being placed

in the receiving vessel B. The tube D E is furnished with a small upright funnel tube *d*, by means of which the space between *b c* and D E can be filled with water,

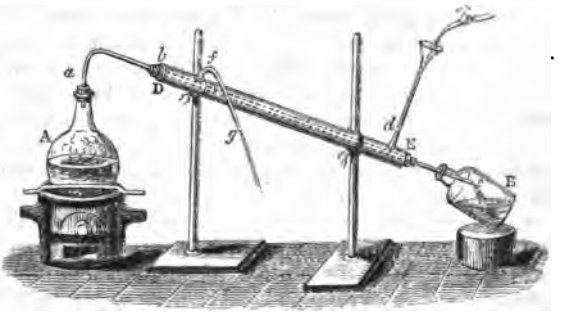


Fig. 12.

which overflows by the tube *f g*. When the water in A begins to boil, its vapour passes into the tube *a b c*, where it is condensed by the current of cold water flowing through D E, and the condensed or *distilled water* collects in the vessel B, the non-volatile impurities remaining behind in the flask A.

9. Pure water has neither taste nor odour: it appears colourless when a stratum only a few inches thick is examined; but when looked through in thicker masses, it is found to possess an indigo-blue colour, which is seen very distinctly in the reservoirs of water where Clarke's softening process is employed, and where, consequently, the bottom of such reservoirs is covered with a white layer of chalk. Usually the water of the ocean appears green, owing to the naturally blue colour being changed by the yellow rays reflected from the bottom, which has usually a yellowish tinge. Water freezes or passes into the solid condition at 32°, which is hence termed its freezing point. By being preserved perfectly quiescent, however, it may be cooled several degrees lower without becoming frozen, but if it be then in the slightest degree agitated, it solidifies instantly. This singular phenomenon is sometimes seen in very cold

weather; when water, which has been standing during the night in a cold room at a temperature below the freezing point, is poured into a basin, it becomes filled with solid crystals of ice, although it was quite free from them before being poured from the ewer.

10. In freezing, water expands very considerably, and with such force as to burst the strongest vessel in which it may be confined; it is thus that water-pipes, &c. are burst during frosty weather. Water has the greatest capacity for heat of all known bodies; that is, it requires a greater amount of heat to raise the temperature of a given weight of water through a certain number of degrees, than is required to warm the same weight of any other substance through the same number of degrees; and consequently in cooling, water gives out a greater amount of heat than any other body. This remarkable property renders the ocean a great magazine of heat, which it receives during the summer and gives out again during winter, thus moderating the extremes of both seasons. It is on this account that the climate of islands is so much more temperate, than that of continents within the same parallels of latitude; the summer being cooler, and the winter warmer, in the former than in the latter. One cubic mile of water, in being heated through 1°, cools 3076 cubic miles of air through 4°, and vice versâ.

11. Water boils, or passes into the gaseous condition, under ordinary atmospheric pressure, at 212°, which is hence termed its boiling point. In thus becoming vapour, water absorbs a very large amount of heat, and expands to an enormous extent, one cubic inch producing nearly a cubic foot of steam. Heated in a close vessel from which the steam cannot escape, the pressure of the latter increases rapidly, whilst the boiling point is also elevated. It is the elastic force of such confined steam that is employed for the production of mechanical force in steam-engines.

12. Water dissolves gases; some to a large amount, as ammonia and hydrochloric acid; others, as atmospheric air and carbonic acid, to a slight extent only. It is to the presence of these latter gases, that the

sparkling appearance and refreshing taste of spring water is due. Fishes can exist only in water containing atmospheric air dissolved, for they soon die if placed in cold water which has been recently boiled, air and most other gases being entirely expelled from water when it boils. Soda-water and other effervescing drinks owe their characteristic quality to a large amount of carbonic acid, dissolved in water under pressure, and which escapes with effervescence when the pressure is removed.

13. Water is also a very powerful solvent for solid substances. When it falls from the clouds as rain, it contains no solid matter in solution; but the moment it reaches the surface of the earth and percolates through its strata, it exerts its solvent action upon the substances with which it comes in contact. When, in this way, it has taken up a moderate quantity of soluble substances, it forms ordinary *spring water;* but when it happens to pass through strata containing much soluble matter, it takes up a larger quantity of foreign materials, and is then called a *mineral water.* Water obtained from wells sunk near human habitations, or from rivers in similar situations, is generally contaminated with putrifying organic matters, which render it deleterious to health if used for domestic purposes; hence it is of the greatest importance, that water for the supply of towns should be brought from a considerable distance, and from a locality where it cannot be rendered impure by such noxious materials.

LESSON III.

NITROGEN AND ITS COMPOUNDS.

1. NITROGEN.—This element is also a gas, but unlike the two we have already considered, it exists in nature chiefly in a free state. In this condition, it constitutes about 79 out of every 100 cubic feet of atmospheric air: it exists, however, also in combination, as an essential constituent of many animal and vegetable substances;—hair, wool, hoofs, horns, flesh, pease, and beans, for instance, contain a considerable proportion of this element. It also occurs in large quantity in certain localities, in combination with oxygen and the alkalies,

under the forms of the nitrates of soda and potash; but these salts have, without doubt, been derived from the decomposition of animal or vegetable substances.

2. Pure nitrogen is best obtained from atmospheric air, in which it is mixed with oxygen and a very minute portion of carbonic acid. The nitrogen can be readily freed from the latter ingredient, by agitating it for a few minutes with lime-water: this is, however, only necessary when absolutely pure nitrogen is required; as the very small proportion of carbonic acid, which exists in air, does not perceptibly interfere with the properties of the nitrogen. To free the air from oxygen, and leave the nitrogen unacted upon, it is only necessary to ignite any combustible substance in a bell-jar of air confined over water as in fig. 13; but in order to obtain the nitrogen pure with facility, it is desirable that the combustible should be of such a nature as to remove the oxygen entirely, and also that the product of combustion may be afterwards readily separated from the nitrogen. These conditions are best attained by the use of phosphorus, which may be placed in a little iron or porcelain cup floating upon water; it must then be ignited, and a bell-jar of air inverted over it, so that its lower edge may dip into the water to the depth of about an inch, as shown in the figure. At first the heat of the burning phosphorus causes the air to expand, and a portion of the latter escapes in bubbles beneath the edge of the jar, but soon the enclosed gas begins to contract, the water rises into the interior of the jar, and finally the phosphorus ceases to burn. During the operation, the phosphorus unites with the atmospheric oxygen, forming solid phosphoric acid, whilst the nitrogen remains unacted upon, the phosphorus having no tendency to combine with this element. The phosphoric acid floats about in the interior of the jar like a white cloud; but after the lapse of a few minutes, it subsides and dissolves in the water, leaving the nitrogen perfectly pure, with

Fig. 13.

the exception of the trace of carbonic acid before mentioned, which may be removed if necessary, by agitating the residual gas with lime-water.

3. Nitrogen is slightly lighter than atmospheric air, its specific gravity being ·9722. In its elementary condition it is distinguished by its negative qualities. It has neither colour, taste, nor smell; it does not support combustion or animal life; a lighted taper plunged into the gas is immediately extinguished (see fig. 14), and, although nitrogen has no positively poisonous qualities, yet an animal ceases to exist when immersed in the gas, simply from the absence of oxygen. Nitrogen is not combustible under ordinary circumstances; but if it be mixed with oxygen and exposed to a very intense white heat, as when electric sparks are passed through the mixture, a small portion of the nitrogen unites with oxygen and forms nitric acid; but this is almost the only mode by which this element, when once free, can be again brought into combination. Before noticing the compounds of nitrogen, it will be necessary briefly to refer to that most important gaseous mixture, which contains so large a proportion of this element.

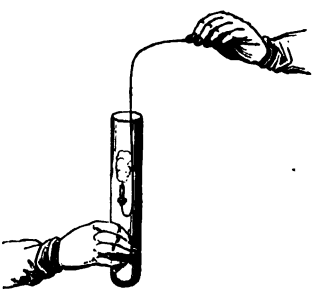


Fig. 14.

4. Atmospheric Air.—This term is applied to a stratum of gaseous bodies, which surrounds our globe and extends to a height of about 45 miles above its surface. These gaseous matters are drawn to the surface of the earth by the force of gravitation; they are consequently densest in the lower regions of the air, where that attraction is greatest, and become more rare as their distance from the earth increases. If the atmosphere possessed the same density throughout its entire mass, its height would be only 5 miles. The principal ingredients of atmospheric air are nitrogen and oxygen,

100 cubic feet of dry air contain about 79 cubic feet of nitrogen and 21 cubic feet of oxygen; or by weight, 100 lbs. of air consist of 77 lbs. of nitrogen, and 23 lbs. of oxygen. In addition to these ingredients, the atmosphere contains about $\frac{5}{10000}$ths of its volume of carbonic acid, a variable amount of watery vapour, which is always present in the air in the dryest weather, and an exceedingly minute quantity of ammonia. It is also extremely probable that the air contains a small quantity of light carburetted hydrogen, but the amount is too small to be detected even by our most delicate tests.

5. So far as is known, the composition of the air has undergone no sensible variation since the creation of man; although there have been constantly causes at work which exercise a most important influence upon the proportion of its constituents; for combustion and the respiration of men and animals remove oxygen and replace it by carbonic acid; so that if these processes went on without compensation, such a large amount of oxygen must be removed and such an increase of carbonic acid occur as to render the air eventually unfit for the support of animal life: by a beautiful arrangement, however, the effects of these processes upon the air are compensated for. In combustion and the respiration of man and animals, oxygen is removed from the air and replaced by carbonic acid; but in the respiration of plants, which is performed during daylight, by means of their leaves and green parts, carbonic acid is removed from the air and replaced by pure oxygen, thus preserving the proportions of nitrogen and oxygen in the atmosphere from any important variation; and such is, in fact, the almost perfect constancy in the composition of the atmosphere, that, although specimens of air collected at various parts of the earth's surface, and brought down from an immense height by balloons, have been analyzed, yet it required the application of the most delicate methods of research to detect the exceedingly-minute difference in their composition.

6. Compounds of Nitrogen.—Nitrogen forms five distinct compounds with oxygen, which contain respectively one, two, three, four, and five equivalents of the

latter element united with one equivalent of nitrogen. The following are the names of these compounds:—

1. Protoxide of nitrogen . . . NO_1
2. Binoxide of nitrogen . . . NO_2
3. Hyponitrous acid . . . . NO_3
4. Nitrous acid . . . . . NO_4
5. Nitric acid . . . . . NO_5

7. PROTOXIDE OF NITROGEN.—This compound is gaseous, and may be best produced by heating dry nitrate of ammonia in a retort, and collecting the gas over water, as shown in fig. 1, p. 141. The salt first fuses, and then, at a higher temperature, disengages a large quantity of gas, being entirely resolved into two equivalents of protoxide of nitrogen and four equivalents of water: the latter condenses in the neck of the retort, whilst the former passes into the inverted receiver filled with water. Protoxide of nitrogen is a colourless and transparent gas, inodorous, but possessing a pleasant sweetish taste. One cubic foot of this gas weighs about one-half more than an equal bulk of air, its specific gravity being 1·527. Although it is gaseous at ordinary temperatures, yet when exposed to the degree of cold at which water freezes (32°), and at the same time submitted to a pressure of about 450 lbs. to the square inch, it condenses to a colourless limpid liquid, which may even be solidified by a very intense degree of cold.

8. Protoxide of nitrogen possesses no remarkable affinities at ordinary temperatures, but it supports the combustion of burning bodies with great brilliancy, when the heat of the combustible is sufficiently high to decompose the gas into its elements, which is the case with most burning bodies: recently-ignited sulphur, however, has not the requisite temperature, and is accordingly extinguished when it is plunged into this gas immediately after ignition, although it continues to burn with great splendour, if it be first allowed to enter into active combustion, before immersion in the gas. Phosphorus and carbon also burn with greatly-increased brilliancy in protoxide of nitrogen; but in all these cases the gas is decomposed by the intense heat of the combustible, which latter then continues to burn in the mixture of

two volumes of nitrogen and one volume of oxygen, resulting from the decomposition of the gas.

9. One of the most characteristic properties of protoxide of nitrogen is its singular effect upon animals when it is respired. Although this gas is ultimately fatal to animal life, yet when pure, it may be respired for a few minutes without any injurious results. Usually the person, who has so respired a few quarts of it, becomes highly excited, makes violent muscular exertions, and not unfrequently laughs most immoderately; in short, the gas produces a species of momentary intoxication, which however, soon passes off without any ill effects. From this property of producing excitement and laughter when respired, protoxide of nitrogen has been not inappropriately named *laughing gas*.

10. BINOXIDE OF NITROGEN. — This compound, which consists of one equivalent of nitrogen united with two of oxygen, is also gaseous at ordinary temperatures. It is never met with in nature, but may be readily prepared by dissolving copper, mercury, and many other metals in nitric acid. Copper is the metal usually preferred, and it ought to be employed in the form of turnings or small fragments; these are placed in the vessel A, fig. 8, p. 146, and dilute nitric acid being poured down the funnel tube, the gas is soon evolved abundantly, and after being allowed first to expel the air from the apparatus, may be collected over water as shown in the figure.

11. *Properties.*—Binoxide of nitrogen is a transparent and colourless gas, of a specific gravity very slightly greater than that of air (1·039). Although submitted to intense cold and very powerful pressure, it has not yet been liquefied. It possesses neither acid nor alkaline properties, but when mixed with atmospheric air or any other gas containing free oxygen, it immediately forms dense red fumes, which are due to the production of compounds of nitrogen, containing more oxygen. This reaction with oxygen is a delicate test for either of the two gases, as the red vapours are distinctly visible, although the gases may be much diluted. Binoxide of nitrogen, has therefore a strong affinity for oxygen, with

which element it forms hyponitrous, nitrous, and nitric acid, according to the proportion of oxygen present, and other circumstances. The elements of this gas are united with much greater force than in protoxide of nitrogen, and it is therefore only with difficulty that it can be made to support combustion. A lighted taper plunged into the gas is immediately extinguished, and this is the case with most burning bodies; but if a piece of intensely-ignited charcoal be introduced into the gas, it continues to burns with greatly-increased brilliancy: ignited phosphorus burns in it almost as vividly as in pure oxygen, and a mixture of the vapour of bisulphide of carbon with binoxide of nitrogen, gives when ignited an insupportably-bright light. In these cases, where binoxide of nitrogen supports combustion, the temperature of the burning body is sufficiently high to decompose the gas, and the combustible then continues to burn in the oxygen thus set free, whilst the nitrogen remains at the close of the experiment, unaffected and in undiminished quantity.

12. *Hyponitrous Acid* and *Nitrous Acid* are two other compounds of nitrogen and oxygen, containing respectively three and four equivalents of the latter to one of the former element. They are very volatile liquids, produced either by the oxidation of binoxide of nitrogen or the deoxidation of nitric acid, and are of comparatively little importance.

13. Nitric Acid.—This is the most important compound of nitrogen and oxygen, and is met with in nature in considerable quantities, combined with the alkalies potash and soda. It is also produced in small quantity, when a mixture of nitrogen and oxygen, containing watery vapour, is heated very intensely, as when a flash of lightning passes through the air. It is, however, generally prepared by distilling its natural compounds, the nitrates of potash and soda, with concentrated sulphuric acid. The mixture is placed in a glass or earthenware retort, and heat being applied, the nitrate is completely decomposed; the sulphuric acid uniting with the base and producing a sulphate: whilst the liberated nitric acid distils over, united with

one equivalent of water derived from the sulphuric acid, and may be condensed in a glass receiver, kept cool by a stream of water flowing over it. The anhydrous acid may be obtained by passing chlorine gas over nitrate of silver; but the process is difficult and attended with danger, as anhydrous nitric acid is liable to spontaneous explosion.

Anhydrous nitric acid forms large colourless crystals which fuse at 86° and boil at 122°. They are readily decomposed and frequently explode without apparent cause. When thrown into water they dissolve, generate great heat, and are converted into hydrated nitric acid.

14. Hydrated nitric acid, generally called nitric acid, contains, in its highest state of concentration, one equivalent of water united with one of nitric acid. It is a very corrosive liquid, one-half heavier than water, and emits dense white fumes in contact with the air. Mixed with water, it produces considerable heat; but when poured upon snow or ice, an intense degree of cold is generated. It boils at 248°. Hydrated nitric acid oxidizes most metals and many other substances with great energy; yielding up usually three of its equivalents of oxygen and becoming converted into binoxide of nitrogen. Its oxidizing powers cause it to be largely employed in the arts.

Compounds of Nitrogen and Hydrogen.

1. Ammoniacal gas. . . NH_3
2. Ammonium . . . . NH_4

15. *Ammoniacal Gas*, or *Ammonia* as it is generally termed, is met with very sparingly in nature, but it is present in the atmosphere in very minute quantity, and is sometimes evolved in the neighbourhood of volcanoes when melted lava flows over vegetable matters. It is also a product of the putrefaction and decay of animal and vegetable substances. It is produced artificially, when animal or vegetable substances containing nitrogen are heated to redness in close vessels, as in the manufacture of coal gas and animal charcoal. From these last sources, our present supply of ammoniacal compounds is now almost exclusively derived.

16. Ammoniacal gas is best prepared by heating a

mixture of one part of chloride of ammonium and two parts of quicklime; in the reaction which ensues, an interchange of chlorine and oxygen first takes place with the production of chloride of calcium and oxide of ammonium, according to the following equation,—

$$NH_4Cl + CaO = NH_4O + CaCl.$$

Chloride of Ammonium. Lime. Oxide of Ammonium. Chloride of Calcium.

But oxide of ammonium cannot exist in a free state, and it therefore instantly splits up into water and ammoniacal gas.

$$NH_4O = NH_3 + HO.$$

The water unites with and is retained by the chloride of calcium and the excess of quicklime, whilst the ammoniacal gas escapes. The latter cannot however be collected over water, because that liquid absorbs it in enormous quantities; but it may be received in a dry inverted vessel filled with air, as shown in fig. 15; for ammoniacal gas is lighter than air, and consequently gradually displaces the latter from any inverted vessel. Nevertheless ammoniacal gas thus collected always contains a small quantity of air, which is, however, reduced to a minimum when the tube conveying the gas is made to terminate near the upper end of the vessel.

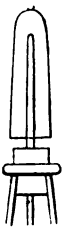


Fig. 15.

17. Ammoniacal gas is colourless and transparent, possessing an intolerable pungent odour and an acid burning taste. It is only about half as heavy as an equal volume of air, its specific gravity being ·589. By great pressure or intense cold, it may be condensed to a colourless and transparent liquid, which immediately resumes the gaseous form when the pressure is removed or the temperature rises.

Ammoniacal gas does not support combustion, but is itself somewhat inflammable, and a jet of it can be burnt in a vessel of oxygen gas, although it cannot be inflamed in air. Water absorbs at ordinary temperatures no less than about 780 volumes of this gas, acquiring its odour in a very intense degree. This solution is usually though improperly termed *liquid ammonia*; it is lighter

than water and powerfully alkaline, neutralizing the strongest acids, with which it produces salts containing the oxide of ammonium as base. A weaker solution of the gas is commonly sold by druggists under the name of *spirit of hartshorn;* and a mixture of the strong solution with various aromatic oils constitutes the so-called *volatile smelling salts.* Ammoniacal gas and its compounds are of great importance in agriculture, as it is chiefly from these compounds that plants derive their supply of nitrogen; and they are therefore largely employed in artificial manures.

18. *Ammonium.*—This body has not yet been obtained in a separate state, but a large number of its compounds are known, in fact all the salts of ammonia contain it; thus choride of ammonium consists of one equivalent of ammonium and one equivalent of chlorine, and the salt commonly called sulphate of ammonia is a compound of sulphuric acid with oxide of ammonium. The compounds of ammonium are therefore produced by the union of ammoniacal gas with acids containing hydrogen.

LESSON IV.

CARBON AND SULPHUR.

1. CARBON.—This element exists in large quantities in nature, though rarely in a pure and uncombined condition. The diamond and graphite are carbon almost completely pure. In combination with hydrogen and oxygen, carbon is a large ingredient in anthracite, coal, and peat: it is also an important constituent of all animal and vegetable substances without exception. Combined with oxygen as carbonic acid, it is present in the atmosphere, and forms more than one-third of the total weight of all limestones and chalk.

2. *The Diamond* is crystallized carbon: it is the hardest substance known, and hence its use for cutting and scratching glass. It is three-and-a-half times heavier than water, beautifully transparent, and refracts light very powerfully. The diamond is combustible, though difficult to be inflamed. When heated strongly in oxygen gas, it takes fire and burns very brilliantly, being entirely converted into carbonic acid gas.

3. *Graphite*, or black lead as it is usually termed, is also a crystalline form of carbon, but opaque and black. It is very sparingly distributed in nature, and is only met with of good quality at Borrowdale in Cumberland. The purest kind is used for black-lead pencils, and the coarser kinds for giving a lustre to iron-work, and for lubricating machinery. Like the diamond, it is difficultly combustible, but burns in oxygen, forming carbonic acid. Graphite is two-and-a-half times heavier than water.

4. *Charcoal* is a non-crystalline form of carbon. It is produced by the decomposition of animal and vegetable substances in a close vessel. Wood charcoal, animal black, lamp black, and coke are varieties of this form of charcoal, and as these are obviously mixed with the non-volatile inorganic constituents of the materials from which they are prepared, the properties of each variety differ considerably. Wood charcoal is moderately hard and brittle, conducts heat slowly, but is a good conductor of electricity. It is quite insoluble in water, and scarcely affected by acids or alkalies. It is very indestructible, and hence the advantage of charring the ends of posts which are driven into the ground. It absorbs large quantities of gases, and when freshly-burnt wood charcoal is exposed to the air, it condenses oxygen within its pores, which enables it to oxidize and decompose any combustible gases or vapours which come in contact with it. On this account it is invaluable for the removal of deleterious emanations from putrifying organic matters, which it consumes and converts into harmless compounds.

Animal-black, *bone-black*, or *ivory-black*, are names given to an impure form of carbon produced by heating bones to redness in close vessels: it possesses the property of removing colouring matters from solutions, and is hence largely employed for decolorising syrups in the manufacture of sugar.

Lamp-black is the soot obtained by burning oils, resin, or other highly-carbonaceous substances with a limited supply of air. It is used as a pigment for black paint.

Coke is the product obtained by heating coal to bright redness without access of air. It is used as fuel where intense heat and a smokeless fire are required.

5. Compounds of Carbon.—Carbon surpasses all other elements in its powers of combination, and in the great variety of compounds into which it enters. The innumerable, and often complex compounds of the organic kingdom, all contain this element, which seems to be quite essential to the formation of organised structures. On the other hand, the inorganic compounds of carbon are few in number, and it will be only necessary for us here to notice two of them, viz., carbonic acid and carbonic oxide.

6. Carbonic Acid.—This compound is gaseous at ordinary temperatures, and consists of one equivalent of carbon united with two equivalents of oxygen. It is frequently emitted from the earth in the vicinity of ancient, but now extinct volcanoes, and exists, as already stated, in large quantity in nature, united with lime—as limestone, chalk, and marble. From any of these natural compounds it may be readily obtained by bringing them in contact with a strong acid. Marble and hydrochloric acid yield the gas most readily and in the state of greatest purity. The marble in fragments may be placed in the two-necked bottle, fig. 8, page 146, and, hydrochloric acid diluted with an equal bulk of water being poured down the funnel tube inserted in *b*, the gas is immediately liberated very copiously, and may be collected over water in the usual manner. Carbonic acid is also generated in large quantity in the combustion of ordinary fuel, the respiration of animals, and the fermentation of beer; but the gas cannot be conveniently obtained pure from these sources.

7. Carbonic acid is a colourless and transparent gas, about one-half heavier than atmospheric air, its specific gravity being 1·525. It has a slightly-pungent odour and an acid taste. Although under ordinary circumstances a gas, yet, when exposed to great pressure, it becomes liquid, and under certain conditions may be even solidified, forming a white porous mass like snow.

Carbonic acid cannot support combustion, or animal life; even when mixed with a large quantity of air, it acts as a poison, and gradually produces stupor and death. A lighted taper plunged into the gas is immediately extinguished. Owing to its high specific gravity, it frequently accumulates in wells, mines, and brewers' vats, occasioning fatal accidents to persons incautiously venturing into them. Water absorbs its own volume of this gas, acquiring a pleasant acidulous taste and a sparkling appearance. Under increased pressure, water can be made to dissolve much larger quantities of the gas, which escapes when the pressure is removed, producing an agreeable effervescing beverage like soda-water. Carbonic acid reddens blue litmus paper slightly, and unites with bases to form a class of salts termed carbonates: this acid is, however, one of the most feeble known, and can be expelled from its combinations by almost every other acid.

8. Carbonic Oxide.—This compound of carbon and oxygen is also gaseous, and has resisted all attempts to condense it into a liquid. It consists of one equivalent of carbon and one equivalent of oxygen, and is one of the constituents of coal-gas. It can be obtained by a great variety of processes, but the simplest method consists in passing carbonic acid over charcoal heated to redness in a porcelain or iron tube, an operation which may be conducted in the apparatus shown in fig. 7, p. 145. The carbonic acid takes up an additional equivalent of carbon in its passage over the ignited charcoal, and is thus converted into two equivalents of carbonic oxide, which may be collected over water as shown in the figure. Very pure carbonic oxide may also be obtained by heating in a flask fitted with a cork and bent tube a mixture of one part of ferrocyanide of potassium with nine parts of concentrated sulphuric acid, the gas evolved from the bent tube being collected over water as before.

Carbonic oxide is a colourless and inodorous gas, slightly lighter than atmospheric air, its specific gravity being 972. It is nearly insoluble in water, and has neither acid nor alkaline qualities. It does not support respira-

tion or combustion, but is inflammable, burning with a blue non-luminous flame and being entirely converted into carbonic acid: the blue flame which is often seen playing above a bright cinder fire is due to this gas. Mixed with half its volume of oxygen, it explodes with violence on the approach of flame.

9. SULPHUR.—This element is found in an uncombined state in the neighbourhood of volcanoes, as an incrustation upon volcanic rocks. It also occurs in much larger quantity, in combination with iron, copper, and other metals, as also combined with oxygen and a base in the form of sulphates of lime (gypsum) and barytes (heavy spar). It is, however, principally from the first source that sulphur is derived, although a tolerably large amount is now extracted from the sulphurets of iron and copper.

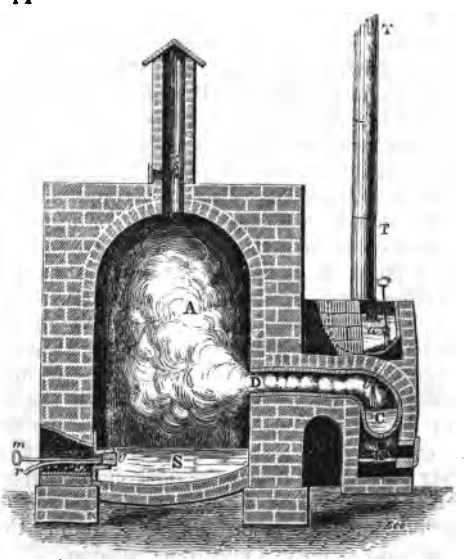


Fig. 16.

10. Sulphur is manufactured on a large scale by the apparatus shown in fig. 16. The encrusted rocks are

placed in the cast-iron boiler M, which is gently heated by a flue from the fire K: the sulphur soon melts out of the rocks and collects at the bottom of M, from which it can be discharged into the body of the retort C D, through the plug-hole *a*. C D is also of cast-iron; it is heated by the furnace K, and its cylindrical neck D leads into a large chamber of masonry A. By the heat of the furnace the sulphur in C is kept in brisk ebullition, and its vapour passes through D into A, where it is condensed and collects in the liquid form on the floor at S, whence, by the removal of the plug *m o*, it is run off, through the spout *r*, into wooden moulds, which give it the cylindrical form of *roll sulphur*. If the operation be so conducted that the temperature of the chamber A does not rise to the melting point of sulphur, the latter condenses in the form of very fine pulverulent crystals, which are called *flowers of sulphur*.

11. Sulphur is a yellow, brittle, crystalline solid, almost exactly twice as heavy as water. When pure, it is tasteless and inodorous. It melts at 226°, forming a mobile liquid, which can easily be poured from one vessel to another; but a further elevation of temperature causes it to become very thick and viscid. At a still higher heat, however, it again becomes more fluid, and at 600° it boils, yielding a vapour of a yellowish-brown colour. If melted sulphur be poured into water when very fluid, it immediately solidifies to a hard, brittle, yellow mass, similar to the sulphur previous to melting; but if, when heated nearly to its boiling point, it be similarly allowed to fall into water, it is transformed into a brown, transparent, very flexible, and elastic substance, which can be moulded by the fingers, or drawn out into threads. It is thus evident that an element can exist in two distinct forms, very unlike each other in external properties, although composed of the same matter: when this is the case, one of the modifications is said to be *allotropic*; thus the soft flexible sulphur is termed allotropic sulphur.

12. Sulphur is a bad conductor of heat and electricity; it is insoluble in water, but soluble, to a slight extent, in alcohol, ether, and oils. When heated in contact

with air above 560° it takes fire, burning with a blue flame, and producing sulphurous acid, a gas of a very suffocating odour. Besides uniting with oxygen in several proportions, sulphur also combines with hydrogen and the metals, producing many highly-important compounds.

13. Compounds of Sulphur and Oxygen.—Sulphur and oxygen unite in no less than six different proportions; but the three following compounds are of far greater importance than the others, and to them we will therefore confine our attention.

Sulphurous acid. . . SO_2
Sulphuric acid . . . SO_3

14. Sulphurous Acid.—This is the only compound of sulphur and oxygen which can be produced by the direct combination of its elements, all other compounds being formed by indirect means. It is produced when sulphur is burned in atmospheric air, or oxygen; but it may be most easily obtained pure, by heating concentrated sulphuric acid with copper turnings. The operation may be conducted in the apparatus shown in fig. 17. The sulphuric acid and copper turnings are placed in a flask, to which a cork and bent tube are attached, the latter leading to the bottom of a second flask, the neck of which is left open. On the application of heat to the first flask, the sulphurous acid gas is disengaged, and, passing through the bent tube, gradually fills the second flask, the gas being much heavier than atmospheric air, which is consequently displaced. The sulphurous acid is here produced by the deoxidation of sulphuric acid, which, yielding one equivalent of oxygen to the copper, is reduced to sulphurous acid: the oxide of copper unites with a portion of the remaining sul-

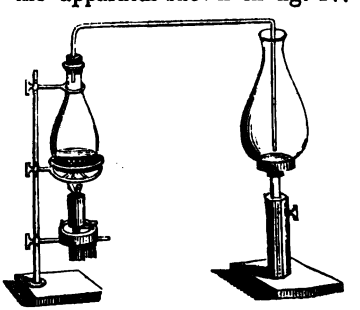


Fig. 17.

phuric acid, forming sulphate of copper. Sulphurous acid is a colourless gas, of a pungent and suffocating odour and an acid taste. It is more than twice as heavy as air, its specific gravity being 2·2105. Under a pressure of about 15 lbs. to the square inch, it condenses to a colourless mobile liquid which boils at 14°. Sulphurous acid gas is not inflammable, and cannot support combustion or respiration. It is very soluble in water, which absorbs no less than 33 times its volume of the gas. Both sulphurous acid and its solution in water have strong bleaching properties, and are employed in the arts for this purpose. When exposed to air in contact with bases, or even with water, it gradually absorbs oxygen, and is converted into sulphuric acid. Sulphurous acid reddens litmus paper strongly, and unites with bases, forming a numerous class of salts called Sulphites.

15. Sulphuric Acid.—This is the most important compound of sulphur and oxygen, both from its important chemical relations and its very extensive use in the arts and manufactures. Pure and anhydrous sulphuric acid may be produced by a variety of processes; thus it is formed when sulphurous acid and oxygen are passed over spongy platinum heated to redness, or when the sulphate of iron or bisulphate of soda is submitted to distillation. In this form it is a white crystalline solid, emitting dense white fumes when exposed to the air. One of its most characteristic properties is its intense affinity for water; when thrown into this liquid, it hisses like red-hot iron under similar circumstances, and is immediately converted into hydrated sulphuric acid. It rapidly carbonizes and decomposes organic substances containing water or its elements. It is, however, in the hydrated form that sulphuric acid possesses the greatest importance, and it is almost entirely in this condition, that it is so largely employed in the arts and manufactures.

16. The hydrated acid is prepared on the large scale in the apparatus shown in fig. 18. A is a kind of furnace, built of brickwork, in which sulphur is burnt in a current of air; an iron pot, containing a mixture of sulphuric

acid and nitrate of potash, is supported in this furnace over the burning sulphur. This mixture produces nitric acid, which, owing to the heat of the furnace, passes off in vapour, and mixes with the sulphurous acid, converting a portion of the latter into sulphuric acid. There is thus produced a mixture of sulphurous, sulphuric, and

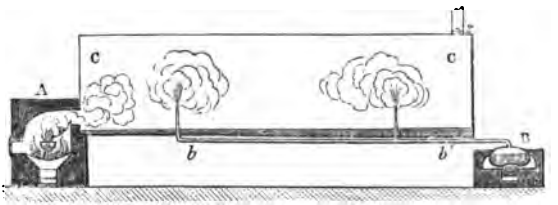


Fig. 18.

nitrous acids, which pass together, along with an excess of atmospheric air, to a large leaden chamber C C, into which a quantity of steam from the boiler B is also injected by the tubes *b b*. The mutual action of the sulphurous acid, nitrous acid, and aqueous vapour produces binoxide of nitrogen and sulphuric acid; the latter dissolves in the water, with which the bottom of the chamber is covered; the former attracts oxygen from the air present in the chamber, reproducing nitrous acid, which, reacting upon new portions of sulphurous acid and aqueous vapour, forms a further quantity of sulphuric acid and binoxide of nitrogen, the latter continuing in this way to transfer atmospheric oxygen to the sulphurous acid until it is finally carried out of the chamber by the exit flue *s*. A comparatively small quantity of nitric acid, originally liberated in A, is therefore capable of converting a large amount of sulphurous into sulphuric acid. The acid which collects on the floor of the chamber in the manner described, contains a considerable quantity of water. To free it from this, it is drawn off and boiled down, first in leaden vessels, and finally in vessels of glass or platinum, until it contains one equivalent only of water, united with one equivalent of anhydrous sulphuric acid. The acid thus left, after evaporating the superfluous

water, is frequently termed *oil of vitriol*: no further evaporation can separate from it the remaining equivalent of water.

Monohydrated sulphuric acid is an oily liquid of sp. gravity 1·848, boiling at 617° and freezing at −31°. It is the strongest acid known, and is powerfully corrosive, extracting water from, and thereby charring, organic substances. Mixed with water it evolves great heat, and its strong affinity for this liquid renders it very useful for drying substances, which it is desirable to free perfectly from water. Sulphuric acid is much used in chemical researches; and its manufacture on the large scale is of the highest importance, as upon it depends the commercial production of soda-ash, soap, glass, and bleaching-powder.

17. Hyposulphurous Acid.—This acid cannot exist in a free state, for it is immediately decomposed into sulphurous acid and sulphur, when it is liberated from its salts by the addition of a stronger acid. In combination with bases, however, it forms a class of salts of considerable permanence. The hyposulphite of soda is the most important of these salts; it is most easily produced by boiling a solution of sulphite of soda with sulphur in fine powder. The sulphurous acid, in the sulphite of soda, unites with an additional equivalent of sulphur, and thus becomes hyposulphurous acid, which remains united with the soda.

$$NaO\,SO_2 + S = NaO\,S_2\,O_2.$$

Hyposulphite of soda is a colourless crystalline salt, which possesses the property of dissolving several of the insoluble salts of silver. This has led to its extensive use in photography, for fixing, or rendering permanent, the pictures obtained by the action of light. It effects this by dissolving from the material, upon which the picture is obtained, the compounds of silver, which, if suffered to remain, would be sensitive to the further action of light.

18. Compounds of Sulphur and Hydrogen.—Sulphur forms two compounds with hydrogen, but one of them only is of sufficient interest to be noticed here;

this is *hydrosulphuric acid*, or *sulphuretted hydrogen* as it is generally termed. Sulphuretted hydrogen is gaseous, and consists of one equivalent of sulphur united with one equivalent of hydrogen. It is immediately produced in abundance, when dilute sulphuric acid is poured upon fragments of sulphide of iron. The following equation expresses the reaction.

$$FeS + SO_3 HO = FeO\,SO_3 + HS.$$

The operation may be conveniently conducted in the apparatus shown in fig. 8, page 146. But the gas should be collected over a saturated solution of common salt, as it is very soluble in pure water.

19. Sulphuretted hydrogen is a colourless gas at ordinary temperatures, but may be condensed to a liquid under great pressure. It is slightly heavier than atmospheric air, and possesses a most insupportable odour, somewhat resembling putrid eggs. It is inflammable, burning with a blue flame, and producing sulphurous acid and water. It neither supports combustion nor respiration, and in a concentrated form, is very noxious to animal life. Sulphuretted hydrogen is frequently evolved in the earth, by the decomposition of iron pyrites, and, becoming dissolved in water, forms sulphurous springs, such as those at Harrowgate and elsewhere. Sulphuretted hydrogen has a slightly-acid reaction; it acts energetically upon most metallic salts, forming insoluble sulphurets, which have frequently such characteristic colours, as to render this compound a most important reagent in chemical analysis.

LESSON V.

SELENIUM, TELLURIUM, ETC.

1. SELENIUM AND TELLURIUM.—These elements are closely allied in their chemical properties with sulphur, but, as they are of very rare occurrence, a short notice of them will suffice.

2. *Selenium* is a dark-brown solid, which does not readily crystallize; it fuses at 390°, and boils at a much higher temperature; it is about four-and-a-half times heavier than water, and insoluble in that liquid. Selenium forms two compounds with oxygen, which are

analogous in composition and properties to sulphurous and sulphuric acid, they are—

Selenious acid. . . SeO_2.
Selenic acid . . . SeO_3.

3. *Tellurium*, although a true metal in its physical properties, having a strong metallic lustre like silver, yet forms two compounds with oxygen exactly analogous, the one to sulphurous and selenious acids, and the other to sulphuric and selenic acids. These compounds are, however, of no further importance.

4. Phosphorus.—This important element is never met with in nature in a free state; but combined with oxygen, as phosphoric acid, it forms one of the principal constituents of the bones and teeth of animals; and is present in small quantity in every fertile soil. Phosphorus can be best prepared from calcined bones: these consist principally of basic phosphate of lime, which, being decomposed by sulphuric acid, yields insoluble sulphate of lime and soluble acid phosphate of lime. The latter, being separated from the former by filtration, is evaporated to dryness and mixed with charcoal; the mixture is then placed in an earthenware retort, and submitted to distillation at an intense red heat; at this temperature the charcoal combines with the oxygen of the phosphoric acid, forming carbonic oxide and carbonic acid gases; whilst the phosphorus is set free and distils over into a receiver, where it collects below the surface of water. It is purified by redistillation.

5. Phosphorus is a colourless, translucent, wax-like solid, of specific gravity 1·77. It melts at 113° and boils at 572°. It is tasteless, but emits a garlic odour, is insoluble in water, but soluble in alcohol, ether, and oils. Phosphorus is very poisonous. When exposed to the air it evolves white vapours, due to a slow combustion, which is perceptible in the dark, both the phosphorus and the vapours proceeding from it appearing beautifully luminous. It inflames when heated in the air a few degrees beyond its melting point, and as this heat can be easily attained by friction, especially in contact with the fingers, operations with phosphorus are attended with considerable danger, and the more so, as a burn

from this body is more severe than that from any other material. It should therefore never be cut or handled except under water.

6. Compounds of Phosphorus with Oxygen.—The principal compounds of phosphorus with oxygen are

Phosphorous acid. . . PO_3.
Phosphoric acid . . . PO_5.

It will be seen that these compounds are analogous in composition to hyponitrous and nitric acid, and this analogy extends to nearly all the compounds of phosphorus and nitrogen; thus establishing a close connection between these two elements, and causing them to be placed in the same division.

7. Phosphorous Acid.—This acid is produced when phosphorus undergoes slow spontaneous combustion in air or oxygen; it is an acid of considerable power, and readily attracts oxygen, becoming phosphoric acid. Phosphorous acid is tribasic, and its salts are termed *phosphites*.

8. Phosphoric Acid.—This acid is contained, as already mentioned, in bones in considerable quantity, and from these it can be extracted in the hydrated state, by decomposing them with sulphuric acid, which combines with the lime forming a sparingly soluble sulphate, which is separated from the solution of the liberated phosphoric acid by filtration. The solution is then evaporated to dryness and heated to redness, when hydrated phosphoric acid is left. The anhydrous phosphoric acid is obtained by burning phosphorus in atmospheric air, as shown in fig. 19. The acid collects on the plate and sides of the glass, in snow-white flocks.

Fig. 19.

9. Anhydrous phosphoric acid is a white, light, pulverulent solid; it has a very powerful affinity for water

rapidly attracting it when exposed to the air, and combining with it almost explosively when thrown into water. It then forms hydrated acid, which is soluble in water, forming a powerfully acid solution, which neutralizes the strongest bases, forming three well-defined classes of salts containing respectively one, two, and three equivalents of base to each equivalent of acid.

10. Compounds of Phosphorus and Hydrogen.—Three of these compounds are known viz.

Solid phosphoretted hydrogen . . .	P_2H.
Liquid ,, ,, . . .	PH_2.
Gaseous ,, ,, . . .	PH_3.

All these compounds are produced by pouring dilute hydrochloric acid upon phosphide of calcium. The liquid compound is remarkable for its spontaneous inflammability, which it also communicates to the gaseous phosphuretted hydrogen, when the latter contains a small portion of the vapour of the former. This spontaneously-inflammable gas is readily produced, by dropping a few fragments of phosphuret of calcium into a wine-glass filled with dilute hydrochloric acid: each bubble of gas, as it breaks at the surface of the liquid, bursts into flame, and produces a beautiful annular wreath of white smoke as shewn in fig. 20; and each large ring will be found on inspection, to consist of a number of smaller ones revolving with great velocity.

Fig 20.

11. Arsenic and Antimony.—These elements possess a strong metallic lustre, and all the physical attributes of true metals, but they resemble nitrogen and phosphorus closely in their chemical character. Thus they both form acids, analogous in composition to nitric acid, whilst arsenious acid, ($As O_3$) and teroxide of antimony ($Sb O_3$) are also analogous in composition to hyponitrous and phosphorous acids. These elements are met with in nature principally combined with other metals.

12. The compounds of both are highly poisonous, but those of arsenic are pre-eminent in this respect, and

instances of the destruction of human life by its agency are of very frequent occurrence. Like nitrogen and phosphorus, both these elements unite with hydrogen, forming terhydrides, which have the following names and composition:—

Arsenuretted hydrogen . . . AsH_3.
Antimoniuretted hydrogen . . SbH_3.

Both these gases are excessively poisonous, and the preparation of arsenuretted hydrogen, especially, is attended with great danger, several chemists having already fallen victims to the deadly effects of this gas, which is instantaneously fatal even when a few cubic inches only are taken into the lungs.

13. Boron and Silicon.—These metalloids possess a close analogy with each other, and are also connected, though more remotely, with carbon; on which account we have placed them in the same division with the latter element.

14. *Boron* is a brown solid, obtained with difficulty: it is met with only sparingly in nature, and always in combination with oxygen, occurring as boracic acid ($B O_3$) in volcanic districts, diffused in the jets of steam which issue from the clefts of heated rocks. These jets of steam are conducted into small artificial lakes or lagoons, the water of which thus becomes charged with boracic acid. The very dilute solution thus produced is evaporated down by means of volcanic heat, and the boracic acid is finally obtained *in* the crystalline form. It is further purified by combining it with soda, and is then sent into commerce as *biborate of soda*, commonly called *borax*. If a concentrated solution of borax be decomposed by concentrated sulphuric acid, boracic acid is deposited in crystals. Borax is chiefly used in the soldering of metals, and in the glazing of pottery. None of the other compounds of boron are of especial interest.

15. *Silicon* is a highly-important element; but as it occurs in nature in one form of combination only, viz., as *silicic acid* ($Si O_3$), its history may be briefly given. Silicic acid, or *silica*, is one of the most extensively diffused bodies entering into the composition of the

crust of our globe. Sand, flint, rock-crystal, agate, opal, and chalcedony are silicic acid almost perfectly pure; and there is probably no rock or soil in which silica is not present, whilst it is one of the chief constituents of a majority of geological formations. Sea, river, and spring water, also contain small quantities of this compound.

16. Silicon is obtained with difficulty, by acting upon the terchloride of silicon with potassium. It is a brownish-coloured solid, which may be fused at a very intense heat. It possesses no interest. The most important compound of silicon is silicic acid, which exists in two distinct modifications, one of which is soluble in water; the other insoluble. The soluble modification is converted into the insoluble by evaporating its solution to dryness, and by fusing the insoluble modification with an alkali it is rendered soluble.

Silicic acid is a chief constituent of glass, porcelain, and earthenware. It is also necessary to the formation of the stems of grasses and grain crops.

LESSON VI.

CHLORINE, BROMINE, ETC.

1. Chlorine, Bromine, Iodine, and Fluorine.—This division of metalloids is remarkable for the very great similarity of properties of the individual members; they are all possessed of very energetic affinities, and are consequently never met with in nature in a free state. They all unite with hydrogen, forming powerful acids.

2. Chlorine.—This element is gaseous; it occurs principally in combination with sodium, as common salt (chloride of sodium). It is also met with in smaller quantities, in combination with potassium, calcium, and magnesium. By the decomposition of these salts with sulphuric acid, hydrochloric acid H Cl is produced; and by acting upon hydrochloric acid with peroxide of manganese, its hydrogen is oxidized and chlorine liberated.

$$2HCl + MnO_2 = MnCl + 2HO + Cl.$$

The operation may be conveniently conducted in the apparatus shown in fig. 17. The peroxide of manga-

nese and hydrochloric acid are placed in a flask, to which a cork and bent tube are adapted; the latter leading to the bottom of a second flask: on the application of a very gentle heat to the mixture, chlorine is evolved in abundance, and passing to the bottom of the second flask, gradually displaces the atmospheric air. As the gas has a greenish-yellow colour, it is easy to perceive when the whole of the air is expelled.

3. Chlorine, although gaseous under ordinary circumstances, becomes liquid when submitted to a pressure of four atmospheres. It is two and a half times heavier than atmospheric air, has a greenish-yellow colour, and a pungent, suffocating odour. Chlorine is very fatal to animal life: when respired pure, it causes instant death; but diluted with much air, it is not poisonous, and is even administered medicinally to consumptive patients.

4. Chlorine is dissolved by water in considerable quantity. It supports the combustion of many metals, and of phosphorus and oil of turpentine. Some of the metals, as arsenic and antimony, take fire spontaneously when plunged into the gas. It is remarkable for its bleaching properties, and is employed in the arts for this purpose, having superseded the old and tedious mode of bleaching by exposure to air and light. Chlorine unites with oxygen in several proportions, forming acid compounds, which are of an unstable character, and which are frequently decomposed with explosion. *Chloric acid* is the most important of these compounds, and, in combination with potash, forms the salt *chlorate of potash*, extensively used in the manufacture of Congreve matches.

5. Chlorine unites also with hydrogen, forming a powerful acid, the *hydrochloric acid*. This compound is formed when a mixture of equal volumes of chlorine and hydrogen is exposed to sunlight, as described in the First Reading Book, p. 233; but it is most readily obtained by pouring sulphuric acid upon common salt, and conducting the gas which is eliminated, to the bottom of a dry jar or flask, using the same arrangement of apparatus as that described for the preparation of chlorine.

$$NaCl + HO\,SO_3 = NaO\,SO_3 + HCl.$$

6. Hydrochloric acid, also frequently called muriatic acid, is a colourless and transparent gas, condensible to a liquid at a high pressure, possessing a very pungent odour, and an acid taste. When exposed to the air it forms white vapours, which are due to the attraction of moisture. It has a powerful affinity for water, which absorbs a very large quantity of the gas, forming a strongly-acid solution, generally known under the name of liquid *hydrochloric*, or *muriatic acid*. This solution can be readily made in the manner shown in fig. 21 : *a* is a flask containing the mixture of sulphuric acid and chloride of sodium, to which heat can be applied, when necessary, by the small furnace *f*. The tube *b* conducts

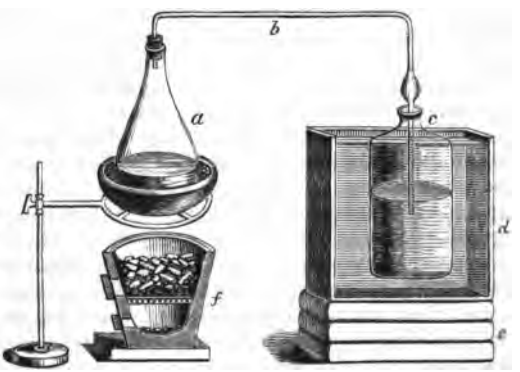


Fig. 21.

the gas beneath the surface of the water, with which the bottle *c* is about half filled. The gas is instantly absorbed by the water, which would soon become heated if the bottle were not placed in a water-vessel *d*, filled with cold water, which is renewed from time to time. Liquid hydrochloric acid is manufactured commercially in large quantities.

7. Concentrated solution of hydrochloric acid is nearly one-fourth heavier than water; it fumes strongly in the air, reddens litmus paper, and possesses all the characters of a powerful acid, uniting with bases, and forming an extensive class of salts, termed *chlorides*. In the

formation of these salts the hydrogen of the acid unites with the oxygen of the base to form water, so that the salt produced consists only of chlorine and the metal of the base.

8. Hydrochloric acid is much used in the arts for the generation of chlorine, and in the manufacture of sal-ammoniac (chloride of ammonium). It is also extensively employed in chemical research, as a solvent for metals and other bodies. Mixed with nitric acid, it forms *aqua regia*, so called from its property of dissolving gold, the king of metals.

Chlorine also forms compounds with sulphur, phosphorus, carbon, &c.; in fact, so extensive is the range of its affinities, that it unites with every other element, except fluorine.

9. BROMINE.—This element is met with in very minute proportion in sea-water, and also in the waters of many saline springs; it is always in combination, and generally with potassium and sodium. When these waters are evaporated, in order to obtain the chloride of sodium which they contain, the liquor left behind, after the separation of the common salt, contains the bromine salts in a state of concentration many hundred times greater than the original water; on passing a current of chlorine gas through this concentrated liquid, the bromine is liberated, and may be dissolved out by means of ether, and from this ethereal solution the bromine is obtained.

10. Bromine is a volatile brownish-red liquid, three times as heavy as water; it has an exceedingly pungent and suffocating smell, and its vapour, in a somewhat concentrated form, is highly poisonous. It supports the combustion of phosphorus and many metals, some of which take fire in it spontaneously. In all its chemical relations, it is almost perfectly analogous to chlorine, and forms similar compounds with oxygen and hydrogen, which have also properties perfectly analogous to the corresponding chlorine compounds.

11. IODINE.—This element is also present in minute quantity in sea-water, in combination with potassium and sodium. Sea-plants assimilate these iodine salts, which

are afterwards found in a much more concentrated state in their ashes; and it is principally from these that iodine is extracted.

12. Iodine is a greyish-black crystalline solid, which melts at 220°, and is converted into a beautiful purple vapour at 347°. It is five times heavier than water, and has a peculiar smell, somewhat resembling dilute chlorine, and an acid taste. It is also highly poisonous, but is sometimes given medicinally, in very small doses. Iodine is slightly soluble in water, but alcohol and ether dissolve it in large quantity, forming dark-brown solutions. Iodine, like chlorine and bromine, combines with metals and phosphorus, but its affinities are much weaker than those of the two previous members of this division. It unites also with hydrogen and oxygen, forming bodies analogous to the corresponding compounds of chlorine.

13. Fluorine.—This element is known only in combination, its affinities being so intensely powerful as to render all efforts hitherto made to isolate it only partially successful; for when expelled from one compound it immediately enters into union with some other body with which it is in contact. It is met with in nature, in combination with calcium, as *fluor spar* (Derbyshire spar). It is also an essential constituent of the teeth and bones of animals. No compounds of fluorine with any of the metalloids, except hydrogen, boron, and silicon, are known; but it appears to be capable of forming compounds with all the metals. Its compound with hydrogen is the most important. This compound is a strong acid, *hydrofluoric acid*, and consists of one equivalent of each element, like the corresponding compounds of chlorine, bromine, and iodine. It is formed by treating any metallic fluoride, as, for instance, fluoride of calcium, with concentrated sulphuric acid, and applying heat. The operation must be conducted in vessels of lead, silver, or platinum, as glass vessels are rapidly corroded by hydrofluoric acid.

14. Hydrofluoric acid is a very volatile and dangerously corrosive liquid, which fumes strongly in the air, and possesses very powerful acid properties; a drop, let fall upon the skin, produces much the same effect as the ap-

plication of red-hot iron, and a very painful sore is produced. Hydrofluoric acid unites with bases, and forms a class of salts called *fluorides;* the same salts are formed when metals dissolve in the acid. But the most remarkable property of this acid is its power of corroding and dissolving glass; even its vapour rapidly acts upon glass, and may be employed for etching upon this material. For this purpose the glass should be coated with a thin film of wax; the design being then traced upon the wax by a pointed instrument, the plate is afterwards exposed to the vapour of hydrofluoric acid. The glass becomes etched, wherever the instrument used to trace the design has cut through the coating of wax. Glass tubes and other scientific instruments are very conveniently and accurately graduated in this manner.

E. FRANKLAND.

LESSON VII.

LIFE OF SIR HUMPHRY DAVY.

BY HUGO REID.

1. THE science of chemistry, which exhibits so many curious and striking phenomena, and is so rich in its applications to the arts and manufactures, made great progress during the middle and close of the last century and the early part of the present. During that time it was cultivated with great success by Black, Priestley, Cavendish, Davy, and Dalton, in England; by Scheele, in Sweden; and by Lavoisier, Fourcroy, Berthollet, and others in France. The great discoveries were made of the composition of air and water; hydrogen, oxygen, nitrogen, and several other gases were found out; new compounds and new elements were daily added to our previous stores, and mankind were deeply interested by the brilliant and important discoveries with which science was thus enriched.

2. In producing the various phenomena of chemistry, the chemist acts by two principal operations—combination and decomposition. He effects combination when he causes two or more bodies to unite into one homogeneous compound, differing in properties from each o

its components; as when from sand, red lead, and soda, or potash, glass is formed. He effects decomposition when he separates a compound into its component elements; as when from water he extracts the two elements, oxygen and hydrogen. Previous to the close of the last century, the chemist effected combination and decomposition by simply bringing bodies in contact by dissolving them in some liquid, by beating them together, or sometimes by pressure: these were the only means within his reach for bringing about chemical changes. But at that time chemistry was armed with a new power—galvanism; and it is chiefly for the important discoveries he effected by means of this new agent that Sir Humphry Davy ranks as one of the greatest chemical philosophers the world has yet seen.

3. Sir Humphry Davy was born at Penzance, in Cornwall, in the year 1778, of a respectable family in that town. He was sent to a good school at Truro, where he acquired the usual rudiments of education, including the classics. He possessed a great facility in composing Latin and English verse, and was frequently engaged by the other boys to assist them in their exercises. But his facility in composition enabled him to assist them or amuse them in very different occupations from school exercises; he used to aid them in writing valentines, and entertain them with stories which he *improvised*, that is, composed as he went along. His tales were full of incidents of wonder or terror, and so interesting did they prove, that numbers of boys would collect by appointment, under the balcony of the 'Star' inn, to hear him. Fishing was, very early, a favourite amusement of young Davy, and continued so during his maturer years: when a mere child, he is said to have played at angling with a stick, and a thread with a crooked pin tied to it, with which primitive implements he angled in the gutter! In the year 1795 he was apprenticed to Mr. Borlase, a surgeon and apothecary in Penzance; there, in the preparation of various medicines, he had his attention turned to the science of chemistry, in which he afterwards became so distinguished. In 1797 he first made chemistry a special

subject of study. About that time he had the good fortune to become acquainted with Mr. Gregory Watt (the son of the eminent James Watt), a man of ability and superior scientific attainments. Mr. Watt was much interested by the ardour and genius of young Davy; a warm friendship grew up between them; they studied together the mineralogy and geology of the district; and, partly through the friendship of Watt, Davy obtained an appointment which afforded him a field for the development of his genius and the cultivation of his now favourite science—chemistry.

4. Soon after the gases had been discovered, and their properties investigated, it was conjectured that the respiration of several of these gases, or of mixtures of them with air, might be beneficial in various diseases, and an institution was established at Clifton, near Bristol, with the view of experimenting on the subject. It was founded, mainly, by Dr. Beddoes, the elder Watt, and the well-known Mr. Wedgwood, and was called the *Pneumatic Institution*. In 1798 Davy was appointed to superintend it—to direct the preparation of the various gases, to administer them, and investigate their effects. There he prosecuted diligently the study of chemistry; published in 1799 a volume entitled 'Researches, on Heat and Light,' and in 1800, the volume which laid the foundation of his reputation, 'Researches, Chemical and Philosophical, chiefly concerning Nitrous Oxide and its Respiration.' This remarkable gas is now well known under the name of *laughing gas*, or *intoxicating gas*; soon after its properties were discovered, it was called *pleasure-giving air*.

In this work Davy unfolded the best methods of procuring this compound and of developing its singular properties. He had the boldness to ascertain its effects on man by breathing it himself—a hazardous experiment—for some of the gases are extremely acrimonious and irritating, as chlorine; others are highly poisonous, as sulphuretted hydrogen and carbonic acid. He breathed it first mixed with air in various proportions, and then pure or unmixed, and found, to his surprise, that it possessed an exhilarating or intoxicating effect; stim-

lating the circulation, exciting the imagination, raising the spirits in a remarkable degree, and causing most agreeable sensations. It has been found, however, not to affect all alike; it moves some to uncontrollable and violent laughter, whence one of its names; others break forth into animated speech, declaiming with unusual energy and volubility; while there are some who are rendered pugnacious by it, and after inhaling it, immediately begin to strike right and left at all around them. It endues them with remarkable strength for a time, but its effects soon pass away. This singular gas consists of the same components as atmospheric air, but in different proportions.

5. In 1801 Davy left the Pneumatic Institution, and went to settle in London. The anticipations that a powerful aid in the cure of diseases would be found in the various newly-discovered gases turned out fallacious; but Davy had established his reputation, and in 1802 he was appointed professor of chemistry at the Royal Institution in London, having acted as assistant-professor in the previous year.

In his new career Davy was eminently successful. His lectures, full of interest and eloquence, attracted crowded audiences, and his papers in the 'Philosophical Transactions' extended his fame. In the year 1800 Nicholson and Carlisle had discovered the decomposition of water—its separation into its elements, hydrogen and oxygen—by the voltaic battery. Davy applied himself to the investigation of the chemical effects of the new power. He soon proved the remarkable connection between chemical action and that of the battery, showing that the power developed is caused by the chemical changes going on between the metal and the acid solution. But his greatest discovery was made in 1807: this was proving the metallic composition of the alkalis, potash and soda.

6. It had long been known that various metals—as iron, lead, quicksilver—rusted, that is, became converted into an earthy matter on exposure to air, losing their lustre and other metallic properties. Since oxygen and the composition of the air had been discovered, it was

ascertained that this earthy matter was a compound of the metal with oxygen—a metallic oxide as we now term it; and it was conjectured that, perhaps, other earthy bodies, as lime, potash, soda, &c., might also be composed of some metal in union with oxygen. It was reserved for Davy to prove that this really was the case; and he first effected the decomposition in 1807, by means of a powerful galvanic battery. He subjected a piece of moistened potash to the action of the battery, and, "to his great surprise, found metallic matter formed." "This matter," he says, "instantly burnt when it *touched water*—swam on its surface, reproducing potash. In dry oxygen gas, likewise, it burnt into perfectly dry potash."

7. This great discovery marked a new era in chemical science; and soon soda, and lime, and other earths were found to be metallic oxides. The remarkable metals, potassium and sodium, were thus discovered, presenting the unusual circumstance of metals being lighter than water, and at ordinary temperatures, so soft as to be easily cut with a knife, but still having the metallic lustre, and other properties, entitling them beyond question to be classed as metals. Thus, in time, we came to the knowledge that the minerals which compose the crust of the earth are mostly metallic oxides, that is, compounds of some metal with the widely-diffused element, oxygen. This was the last of the brilliant series of discoveries, regarding the composition of bodies which characterized that period. *Air* had been analysed; *water* had been analysed; Sir Humphry Davy's discovery led to the analysis of *earth*; and though chemistry has made rapid advances since the time of Davy, there has been none equally important and extensive in its applications as his great discovery, that the alkalis and earths are compounds of oxygen and a metallic basis.

8. In the year 1811 Davy was knighted, and soon after he was created a baronet, honours which had seldom been bestowed on men of science, and which, therefore, indicated the high estimation in which he was held. About the same time he married a widow lady, Mrs. Apreece. Amongst other less important of h[i]

researches may be mentioned the view he took of the green-coloured pungent gas, obtained from salt, now termed, from its colour, *chlorine*. It had previously been regarded as a compound, its supposed elements being indicated by its name, *oxy-muriatic acid*. Davy first showed that it ought to be regarded as an elementary substance, supporting his view by various arguments and experiments, which have been considered conclusive: he thus threw light on an important class of elements.

9. In 1815 his attention was first turned to a very important subject—the means of preventing explosions of fire-damp in coal-mines. An inflammable gas, somewhat resembling coal-gas, is produced in coal-mines, and when mixed with air and exposed to flame, explodes, causing the most fearful destruction of life. Sometimes nearly a hundred lives have been destroyed at once by an explosion of this gas in a coal-mine. The mine is dark, and the miner must have a lamp to enable him to carry on his work: the flame of this lamp sets fire to the explosive mixture of air and fire-damp; so that the poor miner is in this dilemma: if he has no lamp, he cannot see to do his work; if he has a lamp to guide him, it will cause the explosion of any of this dangerous mixture with which it may come into contact. The frequent occurrence of terrible explosions in coal-mines, about the beginning of the present century, had led some ingenious men to the idea of contriving a lamp which should afford light to the miner, but which should not set fire to any inflammable mixture around him. Dr. Reid Clanny, of Sunderland, in 1806, first conceived the happy idea of a safe lamp to burn in mines. By means of water he separated the flame of the lamp from the external air, and supplied the flame with air by means of a pair of bellows. Dr. Clanny's lamp was safe, but bulky, cumbrous, and inconvenient, so that it was not much used.

10. Sir Humphry Davy, being invited by some leading proprietors of coal-mines to investigate the subject, with the view, if possible, of contriving a lamp which should combine lightness with safety, applied his mind

to it, and ere long succeeded in producing a lamp, which, in some form or other, has since been in general use. Flame, or a heat equal to that of flame, was found necessary to ignite the explosive mixture; it had been ascertained that flame would not pass through narrow tubes, and that the smaller the diameter of the tube, the less distance would flame pass along it. Improving upon this idea, it occurred to Sir Humphry Davy to try wire-gauze, which may be regarded as a series of very short, but very narrow tubes. He found that wire-gauze intercepts flame; that if there be an explosive mixture on one side of a piece of the gauze, a flame applied close to the other side will not ignite the mixture; the hot gas from the flame will pass through the meshes; but not in the state of flame, and not sufficiently hot to ignite the gas on the other side. Hence, Davy formed a safety-lamp, by closing the lamp above and below, and surrounding the flame with a cylinder of wire-gauze. The air to support the combustion of the wick enters through the gauze; if any inflammable gas enters with it, the mixture takes fire inside the cylinder, but the ignition is confined to that, and does not spread to the portion without. The enlarged flame gives warning of the presence of the fire-damp, while the gauze confines the explosion to the small portion within the gauze cylinder. In this way the safety-lamp, or *Davy*, as it is termed, enables the miner to work with safety, where, otherwise, dangerous explosions would take place, and thus it has saved the lives of thousands of those who labour for us in the dark and dreary mine, raising from the bowels of the earth the valuable mineral that warms and cheers us, gives us light for our streets and dwellings, assists in preparing our food, and in forming the steam which does so much useful work for us in the factory, the steam-boat, and the railroad. In some few cases the Davy has failed in preventing explosions; in others, there have been terrible accidents, from carelessness in the management of it; it is understood to be still capable of improvement, but remains, notwithstanding, one of the greatest gifts of science to man.

11. These are some of the leading discoveries and inventions which render illustrious the name of Sir Humphry Davy. In 1821 he was elected to the highest scientific position in this country—the presidency of the Royal Society. He lived much abroad during the later years of his life, and died at Geneva in the year 1829. Besides his papers in the 'Philosophical Transactions,' he published a valuable work on the application of chemistry to agriculture, and two elegant works entitled 'Salmonia' and 'Consolations in Travel; or, the Last Days of a Philosopher.' He wrote many poetical pieces, and is considered to have possessed a fine genius, which might have raised him to distinction as a poet had not the superior attractions of science drawn him into another field. His 'Salmonia' and 'Last Days of a Philosopher' are of a highly-imaginative character, and are two of the most delightful works on science, adapted to the general reader, in the English language.

HUGO REID.

Arts and Manufactures.

LESSON I.

THE MANUFACTURE OF GLASS.

BY GEORGE SHAW.

1. MANY chemical compounds which are solid when cold, and liquid when heated to redness, assume a crystalline texture on cooling and solidifying; others, on cooling, assume an *amorphous*, or non-crystalline, structure; the latter compounds are called *glass*. The compounds capable of forming glass, by fusion and cooling, are few; they are principally salts of silicic and boracic acids; that is to say, compounds of these acids with bases, or metallic oxides. Silicic acid is the chemical name for flint, sand, and rock crystal; all of which are composed mainly of silicic acid. The compound of this acid with a base or *metallic* oxide is termed a *silicate*. Some silicates are colourless, others are coloured; some require a high temperature for their

fusion, and others fuse or soften at a low red heat. The silicates of potash, soda, lead, bismuth, and zinc, are colourless; while those of iron, manganese, and cobalt, are highly coloured. The colourless glasses of commerce consist mainly of silicates of potash, soda, lime, and lead: and the coloured glasses consist of these, mixed with the coloured silicates, a small portion of which is sufficient to communicate the depth of colour required.

2. The materials from which glass is made are abundantly distributed in nature; the *silicic acid* was formerly derived from flints (hence the appellation of flint-glass), which were heated and quenched in water, to reduce them to powder; but it is now derived more economically from sand, which is found very extensively in a sufficiently pure state. The sand, in making the best kinds of glass, is first washed and afterwards heated; many impurities are mechanically carried away by the former treatment, and any carbonaceous or organic matter (which has an injurious effect on the colour of the glass), is removed by the latter. As regards the bases or metallic oxides: carbonates of potash and soda are found, in commerce, in a state of sufficient purity; oxide of lead is usually employed in the form of minium or red lead; lime is used in the form of carbonate of lime or chalk; and baryta is sometimes used in the form of carbonate of baryta. The use of lime and baryta is limited by the infusibility of their silicates; as the silicates of the earths, generally, are very infusible, although they readily dissolve in fused silicate of potash and soda. It will now be understood that all kinds of glass consist of *silicic acid*, or sand, combined by fusion, with various *metallic oxides*, principally soda, potash, lime, and lead. The different kinds of glass, such as crown glass, flint glass, &c., consist of different mixtures of these silicates; the composition being varied, in order to bring out those properties which are required in the manufacture of the various articles in which it is employed. It is only by this mixture of different silicates that glass, fit for manufacturing purposes, can be obtained, as no single silicate possesses the requisite pro-

perties. For example, glass composed of silicic acid and potash fuses only at an inconveniently high temperature, and, on fusing, passes somewhat abruptly from a solid to a liquid form; while glass, containing silicate of lead, softens at a lower temperature than the former, and, before becoming liquid, preserves its plastic character, through a wide range of temperature.

3. Not only do the necessities or conveniences of the manufacturer render the admixture of various silicates desirable; but the properties of glass, in relation to solvents, its hardness and brilliancy, are so materially affected by the relative proportions in which the silicates enumerated enter into its composition, that, without these admixtures it would be lost to us in its most valuable uses. Thus, silicate of potassa or soda, or mixtures of them, are dissolved by water, and decomposed by acids. This solubility or susceptibility of decomposition increases, as well as the fusibility, in proportion to the quantity of the potassa or soda present; but, even when their proportion is diminished, until the compound is exceedingly infusible, the glass produced is still affected by water and acids. Silicate of lime, too, containing excess of base, is decomposed by acids; but the mixture of silicate of lime with that of potassa or soda, gives a compound both capable of resisting acids, and fusible at a lower temperature than either of the components separately. Generally, glass is more fusible, and less liable to be attacked by acids, in proportion as it contains silicic acid and alumina; and on the other hand, excess of base gives fusibility and liability to corrosion. Oxide of lead communicates great fusibility and brilliancy, but it also renders the glass soft, and more easily scratched than the glass from which it is absent.

4. With regard to the silicates individually, we may observe, that those of potassa and soda are, under like circumstances, the most fusible of all; their fusibility and solubility varying in proportion to the quantity of alkali they contain. Silicic acid fused with two or three times its weight of alkali, produces a glass fusing at a low red heat, and readily soluble in cold water—by

diminishing the quantity of alkali we may obtain a silicate fusible only in the heat of a forge. The silicates of potassa and soda do not crystallize on solidifying. Silicate of lime is very infusible, and acquires a crystalline texture on cooling, that of magnesia is also very infusible. Silicate of alumina is still more infusible than that of lime or magnesia. The silicates of the protoxides of iron, manganese, and lead, are all readily fusible, and exhibit (the two former in the highest degree) a crystalline texture on cooling. Although described as a mixture, glass should be regarded as compounded of different well-defined silicates, the less fusible dissolved in the more fusible.

5. Formerly, the materials, after mixture, were subjected to a preliminary heating, called *fritting*, whereby water and carbonic acid were driven off: this process is now little used,—the materials, after mixture, being at once introduced into crucibles, in which the fusion is effected. Figure 1 is a section of the pot in which flint-glass is made. A much higher temperature is applied to effect the fusion of the materials than that at which the glass is worked. The fused mass is rendered so liquid, that the bubbles of gas which are evolved, and which consist mainly of carbonic acid, that the silicic acid displaces from the carbonate of potash or soda, rise readily to the surface of the glass and escape. After many hours' exposure to the heat, the whole of the gaseous matter has escaped, and the glass is fit for use.

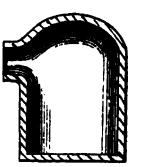


Fig. 1.

6. If the silicic acid and bases employed were pure, the glass thus obtained would be colourless; but as this is an impossible condition, the glass is never colourless—one of the most universally contaminating ingredients is protoxide of iron, which gives a green tint to the glass. The neutralizing of this colour constitutes one of the nicest operations in the manufacture of the finest kind of glass. It is effected by the use of the *peroxide of manganese*. By the introduction of this oxide into the mix-

ture, the protoxide of iron, which gives the green colour, is raised to a higher degree of oxidation (peroxide), which gives but a feeble unobjectionable yellow tint. The peroxide of manganese itself possesses the property of giving a deep amethyst colour to glass, while the protoxide of the same metal has no colouring effect; hence, on the addition of the peroxide of manganese to glass containing protoxide of iron, the former yields oxygen to the latter, passing itself from a colouring to a non-colouring oxide; and, at the same time, causing the iron to pass from a deeply to a slightly colouring oxide. The adjustment of the quantity of peroxide of manganese to the quantity of protoxide of iron present in the glass, requires great care; a deficiency leaves a residuum of green colour, while excess gives a purple hue. The former is technically called low, the latter high, colour.

7. After the glass has been perfectly fused, it is allowed to take the temperature proper to the particular manufacture to which it is to be applied, and after it has been manufactured it has to be *annealed*. The process of annealing is simply the slow cooling of the manufactured articles. This is carried on in annealing ovens, or *lears*, one part of which is more strongly heated than the rest. The manufactured goods are first placed in the hottest part of the lear, and slowly removed to the cooler part, many hours being usually required to effect the slow cooling or annealing of articles thick in substance; thin articles, such as figure-shades, gas-chimneys, &c., require a shorter time, and sometimes are not annealed at all. The use of annealing may be thus explained. Glass is a very bad conductor of heat; so much so that when a large mass at a red heat is plunged into water, the interior of the mass preserves its red heat for a considerable time; and when quickly cooled, the exterior becomes solid, while the interior is yet soft. The outer solidified portions being fixed, and incapable of shrinking with the contraction of the interior as it cools, the whole mass is in a constrained condition—the interior portions soliciting the exterior part to yield, and the exterior resisting, to an extent dependent on the figure

of the mass. The result of this condition in the particles of the unannealed glass is, that a slight accidental circumstance,—the scratch of a diamond, or a minute fracture of a portion of the external surface, determines the balance in favour of the interior particles, and a consequent rupture of the glass ensues. The converse action occasions the fracture of glass on the sudden application of heat; from the imperfect conducting power of the glass, the external layer expands, before the heat reaches the interior; and by this expansion the rupture of the interior portions, prevented by their cohesion from yielding to the enormous force by which the external layers expand, is always effected.

8. Although the annealing of small masses of glass is readily effected, that of large masses is attended with incredible difficulty. Fortunately, optical science furnishes us with the means of ascertaining when the annealing process has been successful. Glass, in common with many other transparent substances, when its particles are in the constrained condition, consequent upon rapid cooling or sudden heating, possesses the property of doubly refracting light. Now, although this double refraction does not take place to such an extent as to enable us to observe the actual separation of a ray of ordinary light into two polarized rays, as may be seen in Iceland spar and other substances; yet, by examining the unannealed glass in a ray of polarized light, the production of colour is sure evidence of a doubly-refracting structure, and the shape of the coloured image informs us of the directions and relative amounts of the several pressures in the interior of the mass. It is only when no colour is obtained by such an examination, that the glass can be pronounced perfectly annealed; a condition which, in the glass used for lenses, and optical instruments generally, is of the utmost importance.

9. Although glass has been described as solidifying in an amorphous or non-crystalline condition, yet it is possible to produce in it a crystalline structure. It has already been remarked that glass may be regarded as composed of different well-defined silicates dissolved

in one another—the less fusible in the more fusible; and it has also been remarked that some silicates have a greater disposition to crystallize than others. By slowly cooling glass containing an infusible and crystalline silicate (one of the earthy silicates), dissolved in a fusible and non-crystalline silicate (silicates of potassa and soda), the former slowly crystallizes from the latter; and in glass containing a large amount of earthy silicates, the formation of crystals may be determined by the application of a heat, lower than that necessary to effect the perfect fusion of the glass. In this case the whole substance of the glass becomes opaque from the formation of minute crystals, and requires a much higher temperature for fusion than previously. Glass so treated is said to be *devitrified*, and is called *Réaumur's porcelain.*

10. The glass ordinarily used for windows is made in two different ways, and the products are distinguished as *crown glass* and *spread glass*. *Crown glass* is made by the process called *flashing*. The glass having been brought into a cup-like form, and being supported on

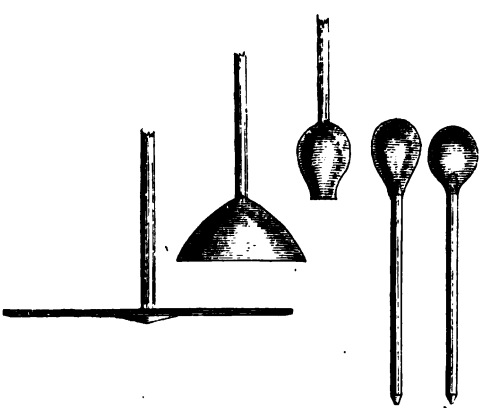


Fig. 2.

an axis or *pontil*, is made to rotate rapidly by the turning of the pontil. The tendency which the particles

of a rotating body have to fly from the centre of motion, causes the cup-shape gradually to expand, and flatten out to a disc in a plane perpendicular to the axis of rotation. On detaching the glass, the disc presents, if it has been produced by a skilful workman, very great regularity of thickness, excepting at the centre, where the pontil was attached. The successive stages in this process may be traced in fig. 2, beginning on the right.

Spread glass is produced in the following manner:— The workman blows a somewhat-cylindrical vessel, the end unattached to the iron on which it is held, is then opened so as to make the whole, excepting the part attached to the iron, of a cylindrical figure. This partially-formed cylinder is detached from the iron on which it was formed, and the hemispherical end by which it was attached being removed, there is obtained a hollow cylinder of uniform thickness throughout. A line drawn by a diamond down the interior of such cylinder parallel to its axis, divides it in the course of the line, and by cautious heating it may be spread out to a flat plate. In fig. 3, these successive steps in the manufacture of the plate may be seen. The glass made by these processes differs considerably; that made by flashing has a brilliancy of surface

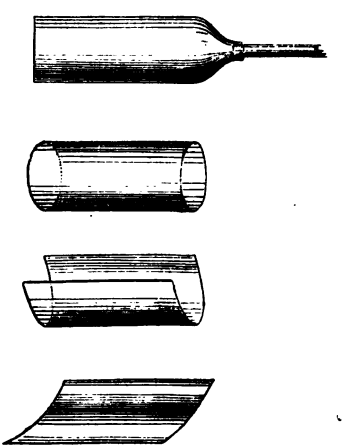


Fig. 3.

which the spread glass rarely approaches, while the latter has a uniformity of thickness superior to the former. In the flashed glass made some years ago, curved lines generally disfigured the surface, and gave a painful distortion to the objects seen through it; this defect, owing to the superior manipulation of the workman, is now nearly obviated. The spread glass, on the other hand, from its uniform thickness, enables objects to be seen through it without distortion; but when it is seen by reflected light, as on the outside of a house, the undulations in the surface, which are always more or less evident, produce a disagreeable effect. Although great improvements in this respect have been made within the last few years, the defect is, in some degree, inseparable from the method of manufacture.

11. When the divided cylinder is softened by heat, and either allowed to flatten by its own weight, as was formerly practised in England, or flattened by the workman, as is now commonly practised, the concave interior of the cylinder has to expand, and the convex exterior to contract, as the curved surfaces become plane. Were this contraction and expansion to take place uniformly throughout the glass, the undulation in question would not occur; but, since one part invariably yields somewhat more readily than another, perfect flatness cannot be attained. If the glass be sufficiently soft, and pressure be applied, a very near approach to flatness may be attained; but the injury which in that case is done to the surface of the glass, more than counterbalances the advantage of superior flatness. Much of the glass made in cylinders is ground and polished after the manner of plate glass, for which, in many cases, it may be advantageously substituted.

12. *Plate glass* is made by removing the crucible, in which the glass has been fused, from the furnace, pouring the liquid mass on a plane surface, and spreading it thereon by means of a roller; the sheet of glass so obtained is afterwards ground and polished. It is in the manufacture of *flint glass* that the arts of moulding, pressing, cutting, and engraving, are principally brought to bear; and these several arts, so simple in principle,

but so difficult in practice, have been brought to a high degree of perfection.

13. In the almost obsolete method of *moulding*, the partially-blown article is introduced into the mould, and by the application of the mouth to the pipe on which the glass is supported, it is distended and forced into the impressions of the mould or die. If the mould was of such figure that the impressed glass could be raised vertically out of it, it was usually made in one piece; otherwise, it was made in two or more pieces jointed together, and held in their places by an assistant while the mould was being used, and opened to permit the article to be removed. Both kinds are shown in fig. 4.

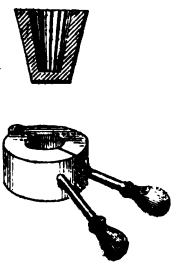


Fig. 4.

14. In *pressing* glass, a suitable quantity of the glass, in a more liquid state than that in which it is used for flowing, is put into the mould, the internal figure of which resembles the external figure of the article to be produced. A solid piston or plunger, fig. 5, having the figure of the interior of the article to be produced, and fitting the collar or neck of the mould closely, is then brought down into the plastic glass, which, by the pressure applied (usually very great), is forced into the minutest impressions of the die. When the article made has sufficiently cooled, it is removed from the mould; and even when its figure has not to be altered it is usually fixed on a pontil, and rapidly heated, so as to soften the exterior film, without softening to an injurious extent the interior of the glass, by which a change of figure or distortion might be produced. The object of this superficial heating is the removal of the slight corrugation which is observed on all moulded or pressed glass, and which is the joint effect of the rapid cooling of the surface by the mould, and the after-contraction of the interior as it cools. Although the sur-

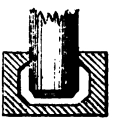


Fig. 5.

face is much improved by the heating described, it is obvious that it can only partially restore the evenness, and that it must, in like proportion, injure all the edges and solid angles of the design. The pressing of glass is now one of the most extensively-practised branches of the flint glass manufacture. Pressed glass is produced with wonderful facility; but the constant repetition of the same form, and the tendency to exuberance and extravagance of ornament, which are inseparable from such a method of manufacture, must prevent it from being employed for the production of other than the commoner kind of articles.

15. The *cutting* of glass is effected by revolving discs of iron or stone, supplied with a moistened cutting-powder, coarser means being resorted to in the first rough fashioning of the design, and finer ones as it approaches completion. The after-polishing is effected by discs of wood and circular brushes; and putty powder (oxide of tin) is used as the polishing material. The forms which can be produced in this way are plane surfaces, concave surfaces, and concave flutes; these can be produced with great precision, and convex surfaces and convex flutes less perfectly. With such seemingly-limited capabilities, the art of glass-cutting, by a judicious combination of these forms, produces designs of the most varied and dissimilar character. The *engraving* of glass is effected by rotating copper discs, supplied with mixtures of oil and emery powders, of different degrees of fineness: these cutting discs have either a convex, a wedge-shaped, or a flat edge; and by the combination of the various forms capable of being so produced, are all the engraved designs in glass obtained.

16. *Coloured glass* next demands attention. It has already been remarked that many silicates possess a deep and characteristic colour; the admixture of these with the colourless ones produce the coloured glasses of commerce. The method resorted to in manufacturing coloured glass is to add the metallic oxide, whose silicate is to be produced, to the ordinary materials used for making glass. Only a few colours present any difficulty. The following are the principal oxides

used for this purpose, and the colours produced by them. Iron-peroxide produces an *amber* colour, which, when deep, approaches red; the protoxide (usually added in the form of scale of iron, a mixture of protoxide and magnetic oxide) produces *green;* cobalt (added as peroxide, but, by losing oxygen, passing into the protoxide, which gives the colour) produces *blue;* sometimes smalt is used, which is itself a glass coloured by cobalt; oxide of nickel gives a fine *brown*, very characteristic, but little used; sesquioxide of chromium produces very fine *green*, as does also the protoxide of copper; but the greens of iron, chromium, and copper, are essentially different; peroxide of manganese yields a fine *purple;* sesquioxide of uranium, the *canary-yellow* colour, introduced within the last few years; carbon (lamp-black) also gives a *yellow* colour. *Reds* are produced by the suboxide of copper, and the *purple precipitate of cassius* (the precipitate produced when a mixture of protochloride and perchloride of tin is added to a solution of chloride of gold), and by the addition of chloride of gold to the batch, or glass mixture; but the production of these colours is attended with difficulty. The former is very intense, and hence is usually flashed or spread in a thin coating on colourless glass. The suboxide of copper has a tendency to pass into the protoxide, which gives a green colour, and hence the presence of a reducing or deoxidizing agent is rendered necessary: this last condition is scarcely compatible with the presence of lead in the glass, lead being easily reduced from the oxide to the metallic state. The red of gold is different from that of copper, and its production is not well understood: the glass containing gold is at first colourless, and only during working or repeated heating assumes a ruby colour. What is called black glass is generally only of a deep purple colour; but a truly *black glass* may be made by a mixture of the oxides of cobalt and iron. *Enamels* are colourless glass, in the substance of which oxide of tin or oxide of antimony is suspended, by which opacity is produced. Phosphate of lime and arsenious acid are also used for the same purpose. Each of these sub-

stances gives an opacity different from that of the other; but we cannot particularize further. By mixtures of the several colouring matters above enumerated almost every tint may be produced.

17. The use of coloured glass is principally confined to the manufacture of windows, but it is also used for vases and other ornamental articles. The coloured sheet-glass used in making painted windows is made in two ways, each, however, being but a modification of the method of making spread glass; that is to say, by dividing and spreading a hollow cylinder. Sometimes the colouring matter pervades the whole of the glass of which the hollow cylinder is made; sometimes only a thin film is spread on one side of the cylinder, and occasionally the same or different colours are spread on both sides of the glass. The first kind is called "pot-metal," the latter "flashed." The object in spreading the colour only superficially is to enable the workman, by removing the superficial glass, to have a colourless surface on which he may paint, in enamel colour, another tint. When the same colour is on both sides, he may, by removing one surface, obtain a lighter tint of the same colour, or a colourless glass by removing both. When the sides are differently coloured, he may obtain the effect of the compound colour or that of either singly, or have a colourless glass. Sometimes a window is constructed of pieces of coloured sheet-glass, cut into the forms proper for each colour, and joined together by the plumber. Such lines or shadows as are necessary to complete the simple design so executed, have previously been drawn or stippled on the glass with an opaque black, fusible, enamel paint, and by the application of heat, have been fused on to its surface. Sometimes a piece of colourless glass is taken, and a design produced upon it by a semitransparent enamel colour being made into paint, and applied with a brush, the after-process of "firing" effecting the partial fusing of the enamel paint and attaching it to the glass. The processes of painting and "firing" are sometimes often repeated when the design is complex or the colours intro-

duced are numerous. It is commonly by a combination of these methods (that is to say, the insertion of pieces of coloured sheet-glass painted upon with enamel colours) that painted windows are produced. The facilities afforded by flashed colours have already been pointed out. It should be borne in mind that, excepting the amber colour produced by peroxide of iron when heated in contact with glass, and one or two others, little used, no transparent colour can (practically) be "stained" upon the surface of colourless glass. All other colours, not produced in the manufacture of the glass itself, are applied by painting, the pigment being a coloured enamel more fusible than the glass itself, and all such enamels have more or less opacity.

18. In deciding what kind of designs in glass should be produced for windows, the means at our disposal, not less than the purpose to which the design, when produced, is to be applied, require careful consideration. The transparent colours are of the utmost purity and brilliancy, but their range is limited, and gradation in the same piece is impossible. The junctions of the several pieces can only be effected by means which leave a black line of separation between them. The only design, then, which can be produced *in transparent colours* is a mosaic, set, as it were, in a black cement. By a very sparing application of enamel-black, lines and shadows may be introduced, which will suffice to indicate rather than to describe a design, without impairing the transparency of the whole. In proportion as the quantity of enamel, whether black or coloured, is increased, a high state of finish may be attained, but at the sacrifice of brilliancy; and the opposite to the mosaic, above referred to, is reached, when there is no colour but enamel colour, and all transparency is lost. Works of art of high character cannot therefore, from the inherent properties of the material, be produced in transparent glass; but there is no substance better fitted for the execution of the conventional forms of heraldry.

GEORGE SHAW.

LESSON II.

PALISSY THE POTTER.

BY J. C. ROBINSON.

1. THE art of Pottery is essentially a useful one, and, on first thought, we should never expect to find any one

individual uniting in himself the qualities and accomplishments of the philosopher, the moralist, the artist, and the working potter; and yet these attributes were so variously manifested in the subject of this memoir, as to render it difficult to decide in which character he is most entitled to consideration—whether as the most philosophic and accomplished of potters, or as the most practical of philosophers.

2. Palissy was born about the year 1509, in the province of Saintonge, a remote district in the south-west of France, bordering on the sea-coast, and died a prisoner in the Bastille in Paris, about the year 1589. Almost all we know of his personal history, during this long

series of years, we have to glean from his own works, literary and artistic; for we find but the scantiest notices of him by his contemporaries, who were all too deeply engrossed in wars and controversies, the favourite topics of a troublous age, to give much heed to his silent, sensible career. Palissy's works, however, constitute his best biography: in them we can trace the various moods of his vigorous and original mind; many incidental passages of vivid word-painting in his writings, giving us passing glimpses of daily life which almost compensate for the want of any regular record.

He published several miscellaneous treatises, the intrinsic merits of which have served to perpetuate his literary fame; but his real reputation rests on the beautiful works in ornamental pottery, so well known as the famous Palissy-ware.

3. There is, however, a peculiar interest attaching to Palissy of a moral or personal kind: it is as a good and true man, as much as in his character of artist and philosopher, that we should regard him; and it is in this light, perhaps, that the most useful lessons are to be derived from his example.

He was originally brought up as a glass-painter, a profession in all probability practised by his father before him. Glass-working, in all its branches, in the middle ages was held to be one of the so-called *liberal arts* noblemen having been allowed to exercise it without loss of rank, if even it did not ennoble the craftsman. The Church was the great protectress of this art; the windows of every village church even being adorned with stained glass, representing in vivid colours, saints, scriptural histories, or legendary occurrences, accompanied with the most elaborate ornaments. The richer laymen likewise caused their armorial bearings, badges, mottoes, or the figures of their patron saints, to be emblazoned in the windows of their dwellings.

4. In pursuance of this occupation, Palissy soon became a proficient in the arts of design: he was, however, by no means content to confine himself within the narrow limits of glass-painting; his acute and reflec-

tive mind appears early to have busied itself with natural philosophy. Habits of minute observation revealed to him, as they will to all of us, a thousand facts of wonder and forms of beauty in every created object. Plants, stones, and minerals, and all the daily phenomena of nature, furnished him with never-failing sources of instruction, which he was ever striving to render of practical account in his art.

At an early age he left his home, to travel about in search of employment and experience, as was then customary with young artizans; and for many years led a wandering life, visiting nearly every part of France, practising his trade of a glass-painter, painting portraits, drawing plans, and surveying land.

5. The age and country in which Palissy lived now demand our attention; for he strongly identified himself with the spirit of the period. France, indeed Europe at large, in the earlier years of the sixteenth century, was in a most troubled state. The period was one of rapid transition, and all sorts of new and disturbing influences were at work alike in war, civil government, and religion. The "Renaissance," or revival of arts and letters, had fully dawned, and the dark and dreary "middle ages," with their feudal system, barbarous ignorance, and contempt of all right but that of the strong, were drawing to a close; ancient civilization was again remembered, ancient learning was eagerly revived, particularly by means of that greatest of all discoveries—the art of printing, and intellect at last made itself a power.

France had recovered from her terrible invasions by the English; the monarchy had gradually acquired unity and consolidation, and the throne was filled by a prince whose character was thoroughly in harmony with the age. Francis I. had been preceded by two kings, who in turn had carried the might of France to foreign conquest, and the battle-ground was Italy, the most polished and highly-civilized country in the world. The successive invasions of that country by Charles VIII. and Louis XII., although they were productive of fearful calamities without any tangible gain, had

had the effect of imparting much of the Italian civilization to France.

6. About this time, also, the disorders and corruptions of the Church seem everywhere to have come to a head, and a feeling was engendered, that the Christian religion and the Roman Church were no longer compatible with each other. Rapidly following in the footsteps of Martin Luther, a host of bold and earnest men sprang up in every country, and, in an incredibly short time, the flame of reformation blazed wildly over Europe. France, as might have been expected from the ardent and impressionable character of her people, was soon impregnated with the new doctrines, the tendency and objects of which were by no means confined simply to the overthrow of religious error. The Church, indeed, was bound up with innumerable political abuses; and every enthusiastic religionist devoted more or less of his energies to the latter questions; whilst, on the other hand, political agitators found it profitable to mix up religious topics with secular grievances. The French reformers were styled Huguenots; and no insignificant mover amongst them was the potter, Bernard Palissy.

7. After his many wanderings, Palissy, about the year 1538, married and settled in the town of Saintes, the chief place of his native province, and from thenceforth we have a detailed account of his occupations and vicissitudes of fortune. He had as yet adopted no settled pursuit likely to lead him to distinction. Natural history and philosophy, as we have said, were the ends towards which his aspirations seem chiefly to have been directed; but his studies in these directions were not of an immediately practical nature, and he was a poor man necessitated to labour for daily bread. We have his own testimony, that to procure this even was no easy task—his principal occupation, that of glass-painting, having gradually declined in public estimation, and ceased to afford a sufficient livelihood. But the cares and requirements of an increasing family, not less than a restless sense of powers unexercised, soon prompted him to seek for more important and lucrative occupation. Whilst thus brooding on vague schemes of in-

vention, chance threw an incident in his way, which directed his future labours and led to enduring fame. It was then that the real greatness of Palissy's character was manifested, and the lesson afforded by this part of his career cannot be too strongly held up as an example to every young person.

We have in fact now arrived at the period of his Essays in the Art of Pottery, the whole course of which was a life-and-death struggle, such as few have had to undergo, and such as fewer still have had the strength and endurance to bring to so successful an issue.

8. Being accidentally shown a beautiful enamelled cup of some foreign manufacture, he was seized with a desire to produce similar works in pottery: it is clear from the wonder and admiration it excited in him, that this piece must have been an excellent specimen of the art, and an entire novelty: it is not improbable, indeed, that it was a piece of Chinese porcelain, then just beginning to be imported into Europe. Whatever it may have been, however, there was a world of weary trial to be undergone, before the faintest approach even towards imitating it could be made; and in the end this intention was abandoned, and an entirely new and original kind of pottery was the real result of his labours.

9. Pottery, at this period (about 1540), was in a very rude state in France, art having very little to do with it. Coarse green, brown, or yellow glazed ware, similar to our kitchen crockery, but ruder and commoner still, was probably produced in all parts of France; but of the manufacture of these even Palissy was utterly ignorant, never having seen the various processes carried out. This, to begin with, was a very great disadvantage; and to have succeeded even up to the current level of the period, without assistance from practical potters, would seem next to incredible: but his ambition went far beyond this. The cup shown to him had a brilliant white glazed or enamelled surface, and was painted with varied colours. At this period, besides Chinese porcelain, only one other kind of pottery answering to this description was made—namely, the Italian earthenware

called *Majolica*, or more commonly *Raphael ware*. It is uncertain to which of these varieties the cup belonged; the latter, however, as well as porcelain, had the peculiarity then quite unknown in France, of being of a brilliant white colour, the dark tint of the clay in the Majolica being concealed by a coating of opaque white enamel glaze spread over the surface. To produce a white enamel for this purpose, then, was Palissy's great object, as he justly deemed the other colours to be of secondary importance.

10. A deeply-interesting and, indeed, dramatic account of his trials and labours henceforth is given in his own essay, entitled "The Artist in Earth." Although his knowledge of glass-painting must have given him a certain insight into the composition of colours vitrifiable by heat, he does not seem, in the outset, to have had any direct clue to the composition of the coveted enamel, and accordingly he set to work mixing and compounding a great number of chemical substances, in the hope of deriving assistance from chance. With these various mixtures he covered innumerable small fragments of unglazed crockery, carefully noting and numbering each piece: these trial specimens were at first fired in the ovens of the neighbouring potters, but as the pursuit grew upon him, he found it necessary to build a furnace at his own house. The idea once firmly rooted in his mind, Palissy prosecuted his researches with incredible persistence; difficulties and disappointments, occurring at every step, only seemed to goad him to renewed exertion, and that too of the severest kind—mental, moral, and physical.

11. Palissy was poor, to begin with, and every day in this seemingly-vain pursuit diminished his slender resources: domestic cares and embarrassments of every kind were the immediate result, whilst the exhaustion of his means prevented him from obtaining any aid in the conducting of his experiments, every mechanical service having to be performed by his own hands, even to the building of his furnace. Day and night his alone was the weary task of tending the fires and supplying fuel, to procure which himself and family

were stinted both in food and raiment. Year after year this feverish struggle went on, uncheered even by a ray of hope; his affairs became worse and worse, till at last utter poverty and starvation seemed inevitable. From time to time he had been obliged to rest from his labours, working hard and hastily in his limning occupation for mere daily bread, and a scanty pittance requisite to carry on his experiments, but these intervals were sorely against his will. His wife sorrowed and his children sickened. Calamities came in all shapes, but there was no halting—no thought of going back—his own existence was staked on success, and he refused to give way. Every pang, every fresh affliction, provoked a quick reaction in renewed endeavours. The only remedy, indeed, for his accumulated misfortunes lay in success, which would bring certain wealth and comfort to his family, and honour to himself.

12. It is impossible, without entering too minutely into particulars, to do justice to this heroic constancy; his own simple and touching narrative alone displays his struggles in their full intensity. His fellow-townsmen and neighbours began at last to think him mad, and to their mockery were added the bitter reproaches of his own wife, whose patience at last entirely gave way. And well it might, for at the climax of his struggles so desperate had he become, that his chairs and tables even were broken up to feed the all-consuming furnace; and finally, when he could procure no other fuel, his house yielded its doors and flooring, and the garden its fence, whilst he himself crouched half naked, starved, and drenched with rain and wintry blasts, for he was unable to provide proper shelter around his furnace, whilst watching through the livelong nights. When, time after time, success appeared all but certain, some cruel unforeseen accident ever arose to dash his hopes to the ground. Many years were spent in this way!

LESSON III.

PALISSY THE POTTER—(*continued*).

1. Success thus perseveringly solicited came at last, though only by slow degrees. Palissy, however, was

not the man to rest satisfied with any partial fulfilment of his task although for a long time every difficulty overcome served but to disclose some fresh obstacle. If he succeeded in the composition of a new enamel, it was perhaps only to find, that its nature was incompatible with those previously discovered; so that often from this cause, when the pieces of ware, on the execution of which he had spent great labour and time, were withdrawn from the furnace, they were found to be utterly spoiled, some of his enamels, having succeeded perfectly, whilst others either remained unmelted or were burnt up and destroyed. Then, again, fragments of the bricks and mortar from his furnace would be found to have fallen on the ware, and to have adhered to the enamel whilst in a state of fusion, completely marring its beauty. At other times, from defects in the construction of his furnace, or from an irregular and deficient supply of fuel, the ware would be fired unequally, so that whilst on one side the enamels succeeded properly, on the other they would be only half melted. In short, so various were the causes of these accidents, and so strange and capricious their occurrence, that it might well have seemed next to impossible ever to hope to overcome them all. But Palissy had seen a perfect example in the cup, which was the origin of his endeavours, and instead of abandoning himself to utter disappointment at each fresh-recurring failure, he wisely, though doubtless often with a heavy heart, set himself to work to investigate the cause of the disaster: thus by frequent failures he acquired experience, until at last practice and observation enabled him to foresee and anticipate results, so that what was in the beginning mere random experiment, became by degrees certain and definite science.

2. In this manner he discovered for himself numerous practical contrivances, which, though probably already known in other countries, had been due to the successive efforts and ameliorations of entire generations of craftsmen; and, judging from results, he appears in some of his methods and appliances to have surpassed even the art of the present day.

3. Palissy's ambition was, from the first, directed to the production of artistic and ornamental works, for he had the inborn genius of an artist: but, when the difficulties attaching to the simultaneous fusion of his enamels and the regular firing of his ware were pretty well overcome, he seems to have prudently made a great number of pieces for domestic use, the sale of which enabled him to carry on his experiments in the manufacture of the more important works, which offered special difficulties not found in the commoner kind. His mind was, however, always bent on producing masterpieces; and, to the last hour of his labours, he never ceased to carry on researches, with a view to the constant perfecting of his works, and it was probably not until after twelve or fifteen years' application that he succeeded in producing the pieces with which we are so familiar. Some description of these will now be desirable. His studies in natural history gave a peculiar bent to his works in pottery; and it is interesting to remark this direct application of one branch of knowledge to another and entirely different one, showing, as it does, how acquirements, which apparently have no reference to our actual vocations, often become singularly available in directions we little anticipated.

4. With the eye and understanding of a naturalist, he felt the full beauty of natural objects; every leaf, or shell, or insect, had a charm for him unknown to the ordinary observer, and, accordingly, he conceived the happy idea of reproducing these objects, in their correct forms and colours, in his pottery, and thus, as it were, of making nature her own artist. In this he was sure of pleasing the unthinking part of the public, by surprising them with the exactness of his imitation, whilst the more refined and reflecting could scarcely fail to admire the tastefully-selected objects for their natural beauty, and to appreciate their artistic display, embellished with the brilliant enamels so novel and exquisite in themselves. Accordingly, the most valuable of his works are his "rustic pieces," or, as he styled them, "rustic *figulines*;" these consist of large dishes, cisterns, fountains, &c., beautifully enriched with all kinds of natural

objects modelled in relief. Of these pieces the most familiar to us are the large dishes, intended to be displayed on the dressers or sideboards of the wealthy, just as silver plate is in our own days. A general description of one of these will give a sufficient idea of the rest.

5. The finest are oval in form, about two feet long and wide in proportion, somewhat deeper and wider in the margin than our modern dishes; this margin represents the mossy bank of a rivulet covered with ferns, daisies, dandelions, ground ivy, wild parsley, and numerous other plants, interwoven with the beautiful confusion we see in nature. These are all imitated in proper relief, all Palissy's works being of the nature of sculpture or embossed work, and, at the same time, every leaf is enamelled in its own proper colours, the various tints of green, peculiar to each plant, being carefully imitated. The dead and withered leaves, the deep brown of the soil, and in short every little accidental tint, are rendered with the utmost fidelity; the lustre and softness of the glazes giving a depth and brilliancy to the entire piece, which render it a most beautiful and effective ornament when seen from a distance. Within this border, or bank, flows a mimic rivulet, encircling the centre of the dish, which forms, as it were, an island adorned with profuse vegetation, the slightly-raised surface of the ground serving to display the brilliant glaze which catches the light, sparkling and changing with every change of position in the spectator. The rivulet flows over a sandy bottom, studded with small pebbles and shells, and in it are fresh-water fishes of various species and aquatic insects. On the bank are lizards, dragon-flies, beetles, tortoises, &c., and in the centre of the dish will perhaps be seen a snake, coiled up and just ready to make a spring at a lizard or other small animal: the whole has the appearance of a world in miniature, reminding us somewhat of the little pools, teeming with animal life, left by the receding tide on some rocky coast.

All the animals represented are actually moulded from nature, and enamelled with the same fidelity as the plants

already described, so that they have a look of actual reality far above any mere artistic invention.

6. It may not prove uninteresting to describe the methods by which these seemingly surprising imitations were executed, premising, however, that the principal difficulties lay, not in the moulding or fabrication of the pieces from the clay, but in their successful firing, and in the beauty and perfection of the enamels, in which latter respect, technically speaking, Palissy's greatest excellence was displayed. We learn from a contemporary manuscript, that the method of forming the "rustic" pieces was as follows:—first, a tin plate was prepared of the exact shape and size of the dish to be made, and on this the natural leaves, fibres, pebbles, shells, &c., were fastened in the required positions with Venice turpentine; the fishes, reptiles, insects, &c., (or more probably casts of them,) were also fastened down with wires and other contrivances, and the whole details carefully arranged, so as to be an exact type or model of the piece to be manufactured. On the original thus disposed a coat of fine plaster was poured, which, when disengaged, formed a hollow mould. In this mould the pieces were afterwards formed by the moist clay being pressed into the cavities, thus again producing an exact repetition in clay of the original model. The lizards, snakes, frogs, &c., so conspicuous for their lively attitudes, were, in all probability, moulded from the living animals, which, when stupified by exposure to the fumes of some narcotic remained rigidly fixed in their momentary attitudes, for a sufficient length of time to admit of a mould being taken from them in plaster, casts from these, as we have said, being fixed down to the tin plate instead of the real animals.

7. The pieces of ware, when taken from the hollow moulds, were carefully finished up by hand and all defects made good, and when perfectly dry were baked or fired in the kiln; in this state they were merely terra cottas, or, as modern potters term it, *biscuit wares*, ready to receive the enamels, which were then carefully applied, probably in a fluid state, when dry having the

appearance of a fine powder loosely adhering to the surface. The pieces were then fired a second time in order to melt the enamels, which then assumed their true colours and lustre, covering the surface of the piece with a coating of fine vitreous glaze.

Besides these "rustic pieces," Palissy produced many others, in which his talents as an inventive artist were more conspicuously displayed; some are decorated with arabesque work of elegant foliage, grotesques, masks, &c., whilst others have figure subjects modelled in relief in a most masterly manner.

8. At length his productions began to attract the attention of the nobles and gentry of the district around Saintes, several of whom became his warm protectors. And by this time protection was needed, for the reformation in France had gradually assumed, on the one hand, the form of open rebellion against the sovereign, and, on the other side, the bitterest persecution of individuals—imprisonment, torture, and burning at the stake for religious causes being of every-day occurrence. Palissy soon became conspicuous for the zeal and earnestness of his advocacy of the Huguenot doctrines, and was at last thrown into prison and in imminent danger of the stake. Shortly before, however, he had found a patron in one of the most eminent noblemen in France, the Grand Constable de Montmorenci, whose influence was then all powerful. At the time of his arrest Palissy was fortunately employed upon extensive works in pottery, for the adornment of the Castle of Ecouen, near Paris, the stately mansion of Montmorenci, and accordingly he was rescued from the parliament of Bordeaux by this powerful friend, who, in order to place him more effectually out of the reach of his persecutors, procured an edict naming him "Inventor of Rustic Figulines" to himself (Montmorenci) and the king.

9. This narrow escape seems to have been the turning point in his career, and henceforth fame and fair remuneration were the reward of his unheard-of toils. About the year 1564 Palissy removed to Paris, and being now a recognised servant of the Court, obtained permission

to erect his workshops in the grounds of the Palace of the Tuileries, where he seems to have remained until the end of his labours.

10. With Palissy's success we lose the thread of his progress in the art of Pottery; we have good evidence, however, that increasing affluence and consideration did not diminish his energies, nor lessen the amount of his labours. Relieved from the all-absorbing cares of uncertain experiments, we find him, whilst by no means neglecting the art which was the main purpose of his life, devoting himself to many other branches of science and literature. He now published several treatises, which brought him increased consideration, and stamped him as a deep and acute thinker, as well as a successful worker. The most interesting of these is certainly his "Artist in Earth," in which he gives an affecting account of his own struggles and the progress of his experiments; besides this, he wrote an account of the troubles that had taken place on account of religion in his native district; also miscellaneous treatises, in which gardening, farming, and fortification, the nature of fossils, rocks, springs, and fountains, and many other branches of science are more or less ably discussed. For many years, likewise, he was in the habit of delivering public lectures on various branches of natural history, illustrated by curious specimens preserved in a museum he had formed. Thus he lost no opportunity of enriching his mind with fresh knowledge, conscious that the only true happiness lies in constant occupation, and that mental and physical health, no less than worldly prosperity, could only be retained by a continued exercise of those faculties, which had raised him from obscurity to an honourable place in the ranks of fame.

11. His latter days, however, were clouded with misfortune; he died in the Bastille after four years of imprisonment on account of his religious opinions, escaping the stake, only because the talents of the old Huguenot potter still excited admiration, even amongst the bitterest persecutors of his co-religionists, and he was allowed to pass the remainder of his life unmolested, though in

captivity. His death, from natural causes, took place in the year 1589, having attained to the extreme age of eighty.

Palissy's pottery is now eagerly sought after by collectors, and sums are given for ordinary specimens even, which would have utterly astounded their author; whilst it is no exaggeration to say, that his choicest works are sold literally for their weight in gold.

J. C. Robinson.

CLAYS.

Hence ductile clays in wide expansion spread,
Soft as the cygnet's down, their snow-white bed;
With yielding flakes successive forms reveal,
And change obedient to the whirling wheel.
—First, China's sons, with early art elate,
Formed the gay tea-pot and the pictured plate;
Saw, with illumin'd brow and dazzled eyes,
In the red stove vitrescent colours rise;
Specked her tall beakers with enamelled stars,
Her monster josses, and gigantic jars;
Smeared her huge dragons with metallic hues,
With golden purples and cobaltic blues;
Bade on wide hills her porcelain castles glare,
And glazed Pagodas tremble in the air.
Etruria! next beneath thy magic hands
Glides the quick wheel, the plastic clay expands;
Nerved with fine touch, thy fingers (as it turns)
Mark the nice bounds of vases, ewers, and urns;
Round each fair form in lines immortal trace,
Uncopied beauty and ideal grace.

Dr. Darwin.

LESSON IV.

POTTERY.

BY L. ARNOUX.

"Then I went down to the potter's house; and behold he wrought a work on the wheels.

"And the vessel that he made of clay was marred in the hand of the potter: so he made it again another vessel as seemed good to him."

1. History has not transmitted to us the names of the first inventors of pottery. It was doubtless one of the first among the inventions which contributed to deliver

man from his state of barbarism. Vessels in *terra cotta*, or baked clay, were probably made by man long before he discovered the art of working metals. The process of baking clay must have had a similar beginning in all countries. It sufficed for a few men assembled round a hearth to notice the hardening of clay by its contact with fire, and conceive thence the idea that this peculiar property might be made available to them by transforming clay into variously-formed vessels, which might serve to contain their drink or their food. The Greeks, who claimed the merit of invention in all arts, ascribed the art of pottery to Corœbus of Athens, who lived 1500 years before the Christian era; but, independently of numerous passages in the Bible to which we could refer, we are fully aware that the Phœnicians and the Etruscans practised the art of pottery at a time when Greece was still in a state of barbarism, and moreover, that the annals of China mention the name of an officer who was appointed by the emperor for the administration of the trade in pottery-ware, at a period which goes as far back as twenty-six centuries before the Christian era.

2. Whatever may be the antiquity of this invention, it is easy to conceive that the men, who first began to work earthy substances, being without any mechanical means, and without the simplest chemical knowledge to aid them, could only prepare vessels of the coarsest kind, without any elegance in form, and so porous that they must rapidly have absorbed whatever liquids were poured into them. It was only, therefore, when other branches of human knowledge had progressed, that potters, seizing in their turn an end of that mysterious link which seems to connect with one another all arts and all sciences, invented a simple machinery to improve the form of their vessels, acquired the chemical knowledge necessary to render those vessels impervious, and attained taste enough to adorn them with colour and designs.

3. Judging solely by what is known of the countries which border the Mediterranean and the Atlantic, it may be said that down to the tenth or eleventh century after the Christian era, that is to say, down to the

period when the Arabs introduced Asiatic processes into the art of pottery, no other than vessels of the coarsest kind, compared with the vessels in use at the present day, were used in those countries. The more perfect among them only exhibit on their surface a vitreous gloss, intended to prevent the infiltration of fatty substances into the body of the ware. However, notwithstanding the coarseness of the material, certain nations, such as the Etruscans and the Greeks, succeeded, by the chasteness of form and the beauty of design, in concealing that coarseness so completely that their vessels acquired a very high value among the various succeeding nations. After the Etruscans and the Greeks, down to the fifteenth century of the Christian era, the art of pottery experienced a continual decline, and it recovered itself only towards the middle of the fifteenth century, owing to the discovery and introduction of enamelled pottery, at a period when a taste for the fine arts arose among most nations of the Continent. Since that period the art of pottery has been in a constant state of improvement with us.

4. Had we to consider, on the other hand, what has taken place in Asia, we should find that the art of pottery has followed a direction totally different. Less skilful than Europeans in the art of producing beautiful forms, the nations of Asia have been at all times much in advance with respect to the manufacturing processes. The discoveries recently made at Nineveh and Babylon have proved that the people under the Assyrian kings understood the art of coating baked clays with transparent and opaque enamels of various colours, and that they used them either to enamel bricks or to inscribe historical designs on plates of clay, or even (as was done in the fifteenth century by Lucca della Robia) to enamel with colours figures in relief. They consequently possessed an extensive knowledge in the art of vitrification, and understood the use of metallic oxides —such as the oxides of lead, tin, copper, antimony, and iron, for colouring enamels. We are inclined to believe that the Assyrians had acquired their notions of pottery from the Persians, and the nations situat-

in the more easterly regions of Asia: those notions were transmitted to the Arabs, who in their turn have shown themselves most skilful in the art of enamelling clays and metals. The Arabs introduced their knowledge into Africa, and afterwards into Spain, whence the art was finally transmitted to Italy in the fifteenth century. Such is the chain which connects the higher kind of ancient pottery with the much improved pottery-ware manufactured in modern times.

5. Although there is at the present day a great variety in the material and quality of pottery, and although each kind requires certain processes peculiar to it, there are, however, some general processes applicable to every kind of pottery, which we shall now explain. Potteries are all made of clays, which, after manipulation, receive certain shapes or forms, and are then submitted to the action of fire. But if every kind of clay can furnish the material of a vessel under the hands of a skilful potter, there are but few clays adapted to the manufacture of utensils of sufficient whiteness, hardness, and resistibility to answer the purposes required in domestic use. Doubtless the ancient potters were obliged, in their state of ignorance, to be satisfied with those clays which they found on the surface of the earth, or in the beds of rivers; but now that we have become acquainted with the nature of all the geological strata of the globe, we have discovered in the lowest of them, that is to say the granitic strata, the materials with which we are enabled to produce our finest porcelain wares.

6. Clays are composed of two essential elements,—silica and alumina. Silica, which represents the vitrifiable element, is generally the most abundant. Alumina, on the contrary, represents the plastic element; and clays are softer and of easier manipulation in proportion to the quantity of alumina they contain. These two elements in clays, when pure, are equally white, and, in this condition, it is hardly possible to mix them together or harden them by means of fire. But clays, in which silica and alumina are found alone, are extremely rare, and, generally, they contain besides either magnesia, oxide of iron, or carbonate of lime.

Clays formed by the decomposition of granite, contain potash or soda. Magnesia, which is a white and infusible substance, like silica and alumina, has properties very similar to those of alumina. Oxide of iron is the colouring matter of clays; all their other elements being white, it follows that the quantity of that oxide, more or less great, determines the colouring of potteries either in yellow, red, or black; and, consequently, the stronger the dose of oxide, the more intense is the colouring. It is therefore necessary for pottery-wares that should be white, that those clays be selected which are without oxide of iron. When lime is found in clay it is always with a mixture of carbonic acid. Clays which contain lime in great quantity rapidly vitrify by the action of heat; but if the heat be made intense, the vessels will not preserve their form, and will melt away to the substance of a blackish glass, similar to the glass in use for common bottles. Such clays are consequently to be avoided; and their nature can always be understood if they are tested with a few drops of an acid (such as muriatic acid), which produces an effervescence, caused by the disengagement of the carbonic acid. Lime contains therefore a property for clays which is called a *flux*, and thereby is understood a matter which combined with silex contributes to form glass. Potash and soda are oxides which act on silica still more powerfully than lime does. These oxides are only found in clays which are formed by the decomposition of felspar, and moreover in small quantities. Felspar is a mineral found in the composition of granite. When it is imbedded in the earth, in particular conditions, it is apt to become decomposed, that is to say, it loses its hardness, and becomes arenaceous. In this state of decomposition, it is deprived of the greatest portion of potash or soda which it contained, and which is carried away by the infiltrations of water through the earth.

7. As a summary of the divers elements which constitute ceramic bodies, it may be said that silica and alumina (sometimes with an addition of magnesia) form the substance of pottery-wares, and make their

white; oxide of iron colours them either in yellow, red, or black; lastly, the *fluxes*, whether lime, potash, or soda, vitrify them, that is to say, give them hardness and sound.

8. When the quantity of flux is great, in proportion with the other elements, the potteries are baked at a low temperature, and in this case the produce is of an inferior kind. When, on the contrary, the quantity is small, a greater heat is necessary in the process of baking, but then the potteries become superior in quality. It is necessary in this place to establish the distinction which exists between glasses and potteries, since their elements are nearly the same. The notable difference is in the proportion of alumina contained in them. Alumina, whilst giving to clays the *plasticity*, which facilitates their manipulation, gives them also, when in sufficient quantity, *infusibility*, or that property by which vessels preserve their shape when they are exposed to the action of a strong fire. It may therefore be considered as forming the bony framework of potteries. Glass, in order to become limpid and of easy manipulation, should be free from alumina. The best pottery, on the contrary, the ware that resists the most blows, and sudden variations in the temperature, is that which contains alumina in the greatest quantity.

9. In the manufacture of articles for common use, the preparation of the clay is very simple. The matter is simply diluted in a great quantity of water, and when the mixture is perfect, the liquid pap, which it forms, called *slip*, is allowed to escape through an opening placed at a certain elevation on one side of the reservoir which has been used. The water thus escaping into another basin carries away the finest and most decomposed particles, whilst the coarser substances sink to the bottom of the reservoir, and are afterwards thrown away. The basin which has received the clay thus purified of its coarse substances, contains a great superabundance of water, and is therefore allowed to remain still for a while, in order that the solid substances contained in it may sink to the bottom, and allow the water to be carried away by means of a syphon. The remaining process consists now in exposing the clay to the heat of

the sun, in plaster vessels of an absorbing nature, or in placing it over furnaces, as practised in England, in order to give it the solidity required for its manipulation.

10. But, in the manufacture of pottery, either white or of a superior quality, the preparation of the clay is an operation both delicate and complicated. After having at first merely mixed several kinds of clays, potters have, by degrees, introduced into the paste, various matters which at first sight did not appear to be intended for the purpose. Thus it was that rocky substances, such as flint, quartz, felspar, and granite; and organic matters such as bones, sands, carbonates of lime and baryta, were successively used for the purpose of giving to the wares whiteness, density, or transparency. Now every one of these substances has advantages or defects of a peculiar nature. For instance, flints, quartz, and sand, whilst they give whiteness, destroy the property of cohesion, and cause brittleness in the ware. Felspar and granites, whilst they give transparency, render the ware more apt to lose its form by the action of fire, and so on with the other substances. We may thereby conceive what care and constant study are necessary in the use of those various substances, in order that each one of them may enter into the mixture only in the proportion which is strictly required.

11. For the purpose of rendering useful this category of substances, each of which is without any plasticity, it is necessary to calcine them at first by means of red heat, so as to render them more friable, then they are ground down to a great state of division. The grinding is managed by the help of powerful mills propelled either by water-wheels or steam. The matters are mixed up in a certain quantity of water, and, under the continued action of large blocks of hard stone wheeled on the bottom of the pan, they are reduced to a very fine pap. Each one of the substances is ground down separately. The person who makes up the mixtures has only then to mix together the different slips in the proportion which he considers the best, being careful, however, to take as the basis of the composition a clay, containing alumina in sufficient quantity so that the mixture

may be worked. When the mixture is complete, it is strained off three times through a fine sieve, called lawn, so as to purify it, and is afterwards placed on a furnace, by which the remaining water is evaporated, and the required consistency of the body is attained. The body thus prepared is ready to receive the form intended for it, and this is effected by three different processes.

12. The first consists in making use of the *wheel*; and this process, which is the most ancient, is particularly applicable to wares of a round form without any ornament in relief. The wheel is a round platform made of wood, mounted on a pivot, put in motion either by the foot of the workman pressing on another wheel placed lower down and larger, acting like a fly-wheel; or by a strap connected with another vertical wheel put in motion by a winch. With both hands the workman manipulates the lump of clay placed on his platform, the wheel being put in rapid motion; and when he has thus roughly prepared the form with his hands, he completes the exact outline or contour by means of a profile made of horn, copper, or slate. A very short time suffices to transform by these means a shapeless lump of clay into elegant and graceful vessels. The invention of the wheel is traced to the remotest antiquity. The Greeks ascribed it to Talus, son of Didulus, who lived 1200 years before the Christian era, and they valued the discovery so much, that they raised a statue in honour of the inventor, and even struck medals to perpetuate his fame: 500 years later the Scythian Anacharsis presented to the Athenians a wheel much improved. Of all nations the Greeks have shown themselves the most skilful in the management of this mechanism so simple in its action, and their vessels still serve us as models for producing the most beautiful forms.

13. The second process used in giving a form to clay is by *moulding*. It is practised for the manufacture of wares which are not perfectly round, or of those, which being round, are covered with ornaments in relief, or hollowed out on their surfaces. This operation requires first of all the preparation of a model executed by a sculptor or modeller. A plaster mould is then cast on that model

(the Romans used to make this mould with clay which they lightly baked). When the plaster mould is dry, it is covered over inside with a crust of soft clay; then the workman, holding in his hand a damp sponge, presses in the clay, in order to make it penetrate all the cavities and sinuosities in the mould. As moulds made with plaster absorb water rapidly, it follows that the clay duly pressed down dries up very quickly, and that the ware can be soon taken out of the mould without any injury to its form. In addition to this all ornaments of high relief, such as handles and spouts, are moulded separately, and, before the drying up of the ware, are fixed to it by means of the same clay in a more liquid state, acting here as glue does with objects of a different nature. The compression of soft clay on a hard substance called a mould, constitutes, therefore, the operation of moulding. In England, for all wares of certain dimensions, even when round, moulding is preferred to the use of the wheel, because as moulding favours the drying up of the ware the fabrication proceeds more rapidly, and, moreover, the workman is not occupied with the form, since it is produced by the mould. It follows that, if the economical results are greater, the workman loses something of his importance, on account of the facility with which his art can be acquired.

14. The last process used in giving a form to wares, and which exclusively belongs to modern art, is *casting*. It consists in pouring the mixture, when still in a liquid state, into moulds made of plaster. The plaster, dried previously, rapidly absorbs the water, and the portion of the mixture which has yielded its water to the mould, forms in the interior a solid crust. When the thickness of this crust is considered sufficient, the remainder of the mixture is thrown away, and the ware is thus moulded by *absorption*, instead of being moulded by *compression*. There are certain clay-pastes which can receive a form by means of this process only. The pastes, for instance, which formerly were used in the manufactory at Sèvres, and which, being almost entirely composed of substances previously vitrified, had lost the plastic property necessary for their manipulation.

LESSON V.

POTTERY—(*continued*). FIRING AND GLAZING.

"Hath not the potter power over the clay, of the same lump to make one vessel unto honour and another unto dishonour?"

1. EARTHEN vessels prepared by any of these three processes are so brittle, before they are baked, that none but experienced hands can touch them. It is therefore necessary to give them the property of resistance required for their intended use. This resisting property is attained by exposing the vessels to an intense heat in ovens of a peculiar construction. The action of heat on all kind of ware should, however, be understood.

2. We have seen that in order to prepare clays for manipulation, it is necessary to dilute them with a certain quantity of water, and thereby form a paste of a consistency similar to that of the dough prepared by bakers for making bread. When, therefore, a vessel is prepared and exposed to the action of the atmosphere, the water evaporates out of it, and as the moisture escapes, it follows, according to the law in physics, whereby bodies of a similar nature mutually attract each other, that the earthy particles approach each other, and as this effect is simultaneously produced through every portion of the clay, it causes a considerable diminution in the bulk of the ware. When the ware appears dry we must not suppose that it has lost all the water contained in it, because those clays impregnated with a great quantity of alumina retain water for a long time even at a high temperature. The vessels are therefore exposed to a great heat, and the effect of this rapidly disengages the water remaining, connects still more the earthy particles together, and, when these particles are so brought sufficiently near they enter into *combination*; that is to say, new bodies are formed of a nature different from the heterogeneous elements which entered into the preparation of the paste.

3. There are two very distinct periods in the *firing* of potteries. In the first, which is the firing at a low temperature, the greatest portion of the water is evapo-

rated, and the earthy particles become sufficiently connected with each other to give sound to the wares, but they still remain very porous, and the alumina, not being incorporated into a substance sufficiently vitrified, still absorbs the water with great energy. This porous or absorbing property is a proof that no *combination* has taken place between the various elements of the paste.

4. In the second period, the firing at *a high temperature*, vitrification takes place, that is to say, the *bases*, such as lime, oxide of iron, potash or soda, produce with the silica glass more or less perfect; whilst the alumina gives consistency to the whole substance, and allows the wares to preserve their shape. Vessels thus vitrified are fit to contain liquids without absorbing them, and they belong to the higher class of potteries, such as stone and porcelain wares.

5. To understand the process of firing, let us imagine a round tower furnished at its base with a certain number of feeders whose mouths convey to the interior of the tower the productions of the fire. The tower is completed at its top by a vault pierced with as many holes as may be necessary to create a good draught. In the empty place within the potteries for baking are placed, care being taken to enclose them previously in round earthen boxes called *saggers*. By this precaution the wares are not in immediate contact with the flame or the ashes, and a great quantity of them can likewise be accumulated in one oven, without injuring by their weight those which are placed below them. The saggers placed inside the oven are piled over one another in the form of columns, of the height of the tower inwardly. When the oven is filled the entrance is bricked in, and heat is produced at first by means of a slow fire, in order that too rapid a disengagement of the water may not cause the wares to crack. Then, as the oven gets warmer, the draught increases, and after a certain time the fire is no longer checked, but as much fuel is allowed as the draught will consume.

6. The duration of the firing and the temperature both depend on the nature of the wares in process of baking. When the required degree of heat has been

attained, the oven is left to cool during two days. After this period, the entrance is unbricked, the saggers are withdrawn, and the wares are found to have acquired the hardness and the colouring intended. When potteries are in this condition they are called *biscuit*. The next important process they have to undergo is *glazing*, or the coating of this rude and porous biscuit, with a vitreous substance intended to produce a brilliant, hard surface, and facilitate the cleaningor washing of the ware.

7. There are several kinds of glazes, for which the following process was formerly much in use. When the heat in the oven had attained a very high temperature, a certain quantity of sea-salt was thrown into the interior by the upper openings of the oven, and under the action of the heat it volatilized. The saline vapours thus formed, when in contact with the surface of the wares, met with a sufficient quantity of silex to form a semi-glaze of silicate of soda. This process of glazing does not require the use of saggers, or, if used at all, they must be pierced. German, Flemish, and English stone-wares used to be enamelled by this process. At present the use is confined to common wares such as water-pipes.

8. Owing to the recent discoveries made in chemistry, the potter is enabled to use a greater variety of substances in the preparation of the glazes. Thus, besides the various preparations of lead and oxide of tin, in use from the earliest times, he has now at his disposal salts of soda and potash, crystal-glass, chalk, felspar, quartz, granites, and even certain clays. The most powerful agents in the formation of glazes are carbonate and oxide of lead, and borate of soda. The substances last named, when in contact with sands and other granitic matters, under the influence of heat, transform them into limpid glass, which only requires the process of grinding to be fit for use. If all the substances used for glazes were insoluble in water, it would suffice to grind their mixture together; but as salts of soda or potash are soluble in water, it follows that if, when the mixture is formed, the biscuit were dipped into it, the salts would become infiltrated into the interior of the biscuit, generally porous

at the time of glazing, and nothing but hard insoluble substances would remain on its surface. It is therefore necessary to vitrify the mixtures previously in separate furnaces, and afterwards to grind in water the glass resulting from the process. All the substance being thus rendered insoluble by vitrification, it is manifest that when the biscuit is dipped in the liquid mixture, the water alone becomes infiltered in the biscuit, and there remains a pulverulent vitreous coat equally distributed on the whole surface. The grinding of glazes, after their fusion, is the same as used for the hard substances entering into the bodies. When the biscuit-wares have undergone the process of dipping in the glaze, another firing is necessary for the purpose of melting the glaze on the surfaces covered by it. This firing is the same as for the biscuit, care need only be taken to isolate the wares from one another, in order that the glaze in melting may not cause them to adhere, and for this purpose, the wares are placed on supporters made of unenamelled clay, whose points or edges are so sharpened that they leave no perceptible marks by their contact. The second firing is generally of less duration than the first one, and, when over, the wares are found as impervious as they would be if entirely made of glass.

9. The composition of glazes is at least as difficult as that of pastes; for if the glazes are too soft or too hard, on the change of temperature, that is to say, the sudden transition from heat to cold, the biscuit and the glaze will not contract equally, and then the glaze will crack in every direction. This defect is called *crazing*. Although very minute, throughout the glaze, these cracks allow the absorption of oily and fatty substances into the biscuit or body of the ware, which thereby becomes deteriorated when in use. The defect called crazing has sometimes been purposely contrived in the manufacture of Chinese porcelain, as it was found that this ware increased in value when a symmetrical arrangement of the cracks accidentally ornamented the surface.

10. Such are the preparations generally suited fo-

every kind of pottery, but each class has distinguishing characters, which we will now endeavour to explain.

Among the dead or unenamelled potteries, the only wares worthy of our attention are those which have been transmitted to us by the Etruscans and the Greeks. The Etruscans originally came from Phœnicia, a country rich in industrious and enterprising men, who were the first to found colonies along the shores of the Mediterranean. The Etruscans having united with the early inhabitants of Italy, founded in that country an extensive empire, which flourished down to the date of 60 years before the siege of Troy. A short time afterwards, Greek colonies came in their turn to fix their abode in Italy, bringing with them the most improved arts of Greece. As the greatest quantity of Greek vases, called Etruscan, were found in Campania, it is thought that the principal manufactures of these wares were established in the neighbourhood of Mount Vesuvius, at Capua, at Cuma, and at Pouzzole. These are the very sites which were chosen by the Romans for their country residences, and where they collected together a great variety of valuable remembrances of ancient art. Greece, on the other hand, was passionately devoted to the ceramic art. Athens, Corinth, and Samos were in high fame for the workmanship of their potteries, and at the time of Pericles a vessel was considered as perfect only when the three great artists of the time—Phidias, Polycletes, and Myron had agreed together in producing the delineation of its form.

11. The period of the Etruscan or Greek manufacture of vases embraces about one thousand years, namely, from 1500 to 500 before the Christian era. But the manufacture, more especially bearing the Italian character, did not last for much more than two centuries, ending 300 before the Christian era. At that period the Romans, who had become rich by their conquests, began to despise mere earthen vessels, and give preference to those made of precious metals. The fabrication of pottery, being no longer encouraged, rapidly decayed, and when a reaction took place in its favour, it was no longer possible to revive the art.

Already, under the first Roman emperors, enormous sums of money were paid for vessels which were considered as ancient. The Greek and Etruscan vases, being intended for ornament rather than for purposes of utility, were mostly turned on the wheel, and received by that process those graceful and even forms which enhanced the value of their paintings. The colouring of these potteries varies with the period of their manufacture. The most ancient have a greyish colour, ornamented with black paintings. Those, on the contrary, of a more recent date, are red, but covered over with a black ground, which allows the colouring of the red clay to remain free, and visible only in the figures and ornaments on the surface. All these wares were baked at a low temperature.

12. In the same class of potteries may be placed the ornaments in terra-cotta, which the Romans have produced in abundance. But we give the name of Roman potteries more particularly to those wares which, manufactured especially for domestic purposes, were coated over the whole of their surfaces with a kind of lustre, or very thin glaze, which gave brilliancy to the colour of the clay. They were not painted and smooth as the Greek potteries were, but moulded and covered with ornaments in relief, somewhat coarsely designed.

13. As early as the year 715 before the Christian era, Numa founded at Rome a college of potters. This city must afterwards have contained a large number of manufactories of potteries, since, even now, hills of a considerable extent within its walls are found to consist of the remains of its ancient potteries. Wheresoever the Romans extended their dominion they carried with them this art, and the conquered countries received it such as it was practised at Rome. Whether in Germany, on the banks of the Rhine, in France, or in England, everywhere the art can be traced to this original source; indeed the potteries of all those places might be considered as originating from the same clay, made in the same moulds, and coated with the same lustre. Probably this lustre was only a sort of glass, made soluble in water. The belief in this is confirmed

by the circumstance that crucibles filled with common glass have been discovered in excavations made in ancient Roman manufactories.

14. Among the other potteries, imperfectly glazed, are found the various kinds of stonewares, glazed, as we have seen before, by means of salt. Stonewares are formed with a very sandy clay, which becomes hard only by being baked at a high temperature. As the pastes which form them are very common, of a dark colour, and cannot endure sudden changes of temperature, they only serve for special wares, such as wine or beer jugs. This kind of pottery was introduced only at the end of the fifteenth century. The most ancient stonewares are said to have been manufactured at this period by Jacqueline of Bavaria, during her captivity in Holland, at the castle of Tülingen. The principal locality of this manufacture was among the German provinces which border the Lower Rhine. During the sixteenth and seventeenth centuries stonewares were manufactured there in a style which recals the forms and ornaments introduced at the period of the revival of arts. Under the reign of the Tudors, stonewares, ornamented with transparent enamels of violet and blue colour, were manufactured in England. Although coarse, they exhibit, nevertheless, a remarkable harmony in their colouring. Much improved stoneware appeared at the beginning of the eighteenth century, and was introduced from Germany by the brothers Ellers. Besides red stonewares, they manufactured also white potteries, enamelled by the process of salt, and covered with ornaments in relief of a superior design. At the present time an infinite variety of wares, in every kind of colour, is manufactured under the general denomination of *stoneware*.

LESSON VI.

GLAZED POTTERIES.

"Burning lips and a wicked heart, are like a potsherd covered with silver dross."

1. GLAZED potteries, properly so called, are divided into two classes. In the one, the glaze is opaque; in the

other, transparent. We have already said that these two kinds of glazing were used in Asia at a very remote period—anterior to the year 522 before the Christian era, the time of the destruction of Babylon by Darius.

2. Potteries coated with opaque glazes are known in Italy by the general name of *majolicas* (thus called from the island of *Majorca*, where they had been manufactured), and the invention is attributed to the Arabs, who, during a long series of centuries, were the guardians of civilization. The Arabs made use of opaque glazes as far back as the tenth century, and probably the tradition of the art amongst them has never been interrupted. In the palace of the Alhambra, in Grenada, and other parts of Spain, the Arabs have given evident proofs of their superiority in the use of pottery for the decoration of public buildings. All opaque enamels receive their property from the introduction of oxide of tin. This substance, introduced into the glazes, hardens them, and gives them a whiteness and an opacity sufficient to conceal the colour of the coarse clay over which they are placed. When oxide of tin is combined with oxide of lead and sand the enamel is white; and in colouring the enamel various metallic oxides are used, such as antimony for yellow, copper for green, cobalt for blue, iron and manganese for black. Opaque enamels were not used in Italy till the beginning of the fifteenth century. A sculptor of that period, named Lucca della Robia, first ventured to coat his terra-cotta works with an opaque glaze. At a later period, the practice was taken up by the potters of the province of Urbino and other neighbouring places. Fortunately, there lived at the time a certain Duke of Urbino, named Guidobaldo, who became passionately fond of these majolicas. He favoured the establishment of a great number of manufactories; and, having collected as many sketches and cartoons of Raphael as it was possible, he had them copied on vessels by the best artists of his day. The *majolicas*, which were manufactured in the lifetime of the Duke Guidobaldo, have at all times been the admiration of amateurs, as much for the

beauty of their enamel and the perfection of their paintings, as for the soft harmony which pervades the whole management of the colours. After the death of Guidobaldo, the manufacture of *majolicas* being deprived of every patronage, rapidly declined under his successors; and although the art was introduced into France and Holland, the wares manufactured afterwards were of very inferior merit.

3. Potteries, in which an opaque body is coated with a transparent glaze, are particularly known by the name of earthenwares. It is very probable that transparent glazes were in use in Europe long before opaque enamels. In fact, a great number of tiles with transparent enamelling are found in the decoration of Gothic buildings. This kind of glaze must have consisted simply of lead ores ground in water. At a later period, potteries very richly decorated with paintings on their biscuit, and often mistaken for *majolicas*, were enamelled by similar process at Faënza, in Italy, whence their name *faïence* in French. Towards the middle of the sixteenth century there lived in France an artist named Bernard Palissy, who acquired a great reputation for the earthenwares, or *faïences*, which he enamelled in various colours. He was a man of talent and energy, and whilst at Saintes, where he established a manufacture, he endeavoured to reproduce the beautiful Italian *majolicas*, without being in any way acquainted with the processes used in their manufacture, and succeeded in producing results altogether novel in their character. The originality of Palissy's wares consists in their ornaments in relief, to which he gave a natural colouring, by means of a coat of transparent glaze of various colours. *Majolicas*, on the contrary, coated with opaque enamels, are decorated on a plain surface with paintings which can be infinitely varied. As the wares of Palissy were manufactured solely for the decoration of apartments, the very projecting reliefs with which they were covered rendered them unfit for any other useful purposes. After Bernard Palissy, his successors showed none of his talents in the preparation of enamels; and being without the artistic

taste so necessary for the production of valuable potteries, it followed, as in the instance of the *majolicas*, that the art decayed; and down to the eighteenth century the manufacture of earthenwares generally offers no feature worthy of remark.

4. It was in England that the art of manufacturing earthenwares was destined to attain its highest degree of perfection. Towards the year 1700 oxide of lead was used by English potters, for the purpose of giving to the potteries a more perfect glaze than could be obtained by salt. A few years later, ground flint was introduced into the paste in order to whiten it, and this process was a very great improvement. But it was only in the year 1763 that Joseph Wedgwood succeeded in manufacturing white earthenwares, much more solid in substance than those manufactured previously, and covered with a transparent enamel of perfect brilliancy. Like his predecessors, Lucca della Robia and Palissy, Wedgwood was endowed with an inquiring and penetrating mind and an exquisite taste, qualities powerfully evinced in the potteries he has left us, and in which our admiration is excited as much by the perfection of their paste and the beauty of their form, as by their decoration in relief. Wedgwood understood that the art of the potter acquires perfection only in proportion to his power of producing agreeable forms. He therefore availed himself frequently of the aid of Flaxman, the most eminent sculptor of his day. Independently of the considerable improvements introduced by Wedgwood in the manufacture of earthenwares, he produced a great number of new potteries of the stoneware class, all of which are remarkable by the highly-finished style of their workmanship. Among them may especially be noticed stonewares, with a beautiful blue ground covered with white ornaments in relief. From the time of Wedgwood a great number of English potters have adopted his principles, and carried his improvements still further, especially in the printing of the colours with which earthenwares are ornamented. The printing of the designs is made on the biscuit, and the transparent glaze, being afterwards melted over the surface, revive the colouring and gives it a great brilliancy.

5. Porcelains belong to an order of potteries superior to the various kinds we have hitherto considered. The first porcelains came from China. The Portuguese introduced them to Europe during the sixteenth century, and it may be said that the greatest progress, accomplished in the ceramic art in Europe, originated in the desire which potters had of reproducing wares which should equal them in beauty. The character peculiar to porcelains is that they are *translucid*, that is to say, that the body of the ware is pervious to light; and moreover that, being baked at a very high temperature, they acquire a hardness which is not possessed by other potteries. There are three sorts of porcelain very distinct from each other. 1st. Hard porcelain, such as is imported from China, and which is identical with Saxony and French porcelain. 2nd. Soft fritted-paste porcelain, such as that made at Sèvres during the second half of the 18th century; and, 3rd, soft English porcelain, very improperly called *china*, in the manufacture of which bones are used in great proportion.

6. It is now impossible to trace the period at which hard porcelains were first manufactured in China. The invention is evidently of great antiquity. China-porcelains have at all times been admired on account of the beauty of their colours as well as the originality of their forms. From the period when they were brought to Europe by the Portuguese, that is to say, 1508, the discovery of the substances with which they were formed became the dream of many among the learned. Ignorant of the process of analysing substances, in order to understand the nature of the elements which composed them, the curious indulged in more or less ingenious hypotheses, which, when tested by experiments, produced no satisfactory results. It was only in 1706 that two Germans, named Ischirnaus and Bottger, who had devoted themselves to alchymy in the service of the Elector of Saxony, and who had vainly sought to discover the philosopher's stone, seriously directed their attention to the art of reproducing Chinese porcelain. Guided by his countryman, who was his superior in the knowledge of chemistry, Bottger succeeded in producing pottery of a deep-red colour, and sufficiently vitrified

for the purpose of receiving a beautiful polish on the wheel, by the process adopted with hard stones.

7. But although the first wares produced by Bottger were called *porcelains*, they were far from deserving the name: two essential qualities were still wanting in them, namely, whiteness and transparency of body. Bottger, therefore, was continuing his researches with ardour, when he ascertained by chance that an adventurer was selling in Saxony, as hair powder, a white earth which, after exposure to intense heat, proved to be identically the basis of China porcelain. Bottger, endowed with the spirit of enterprise as well as of inquiry, very soon manufactured porcelains equal to those of China. The kings of Saxony long preserved as a secret the processes employed in their manufactories; and as they sold their porcelain wares very dear, they secured by their sales an immense amount of revenue. Soon, however, a few workmen having escaped from the principal manufactories established in the Castle of Meyssen (near Dresden), scattered about the provinces of Germany the knowledge of their art, and in a very short time manufactures of hard porcelain were established in the greatest number of states throughout the Continent.

8. Kaolin* forms the basis of hard porcelain; but it rarely contains in itself the properties for producing a white and very transparent body. Certain felspars, in various proportions, according to the nature of the substances used, must therefore be combined with it. As felspar, and still more kaolin, contain but very little of the fluxes, that is to say, of soda or potash, it follows that an extraordinary high temperature is required for the firing of hard porcelains. The greatest difficulty of the process consists therefore in finding, for the construction of the oven and saggers, a clay sufficiently refractory to resist a heat so intense without melting away. With regard to the glaze for hard porcelains, it differs essen-

* *Kaolin.* The Chinese name for porcelain clay. There is a large tract of this substance at St. Austle in Cornwall, on the south side of the granite range. It contains crystals of felspar, quartz, and mica. It is also found in France, Saxony, &c.

tially from all others. It does not require, as with other glazes, salts of soda or potash, or oxides of lead, but only felspar and quartz, so that as much heat is necessary to melt the enamel as to vitrify the paste. They are, therefore, baked together, but with a lighter firing for the paste, in order that it may acquire hardness enough to resist melting when dipped into the liquid glaze. From all that precedes, it may be understood that hard porcelain is the best kind of pottery for domestic use. In fact, its enamel is so hard that the best-tempered steel cannot scratch the surface of it.

9. The finest *soft-paste* porcelain is of French origin, and its principal manufactory was at Sèvres, near Paris. The composition of this ware is very different from hard porcelain. The French had long endeavoured to manufacture a transparent porcelain similar to the China porcelain. Several chemists had imagined that this ware was not a pottery at all, in the strict sense of the word, but that it was a very hard glass. Guided by this hypothesis, after many failures in their experiments, they at last prepared a *frit* (that is to say, an intensely-baked mixture of sand and potash), being careful, during the process, to moderate the quantity of the alkali so that it should be insufficient to produce a melted glass, but yet be capable of whitening the sand, and giving it translucidity. When they had thus produced a frit, they ground it down, adding to it only that quantity of clay which was strictly necessary to facilitate the operation. Such was the substance since called soft-paste, in French *pâte tendre*. The plastic element in its composition was in so small a quantity, that the process for shaping the vessels was of the greatest difficulty, and it became necessary to adopt the process of casting we have described. Whilst soft-paste porcelains were thus successfully manufactured in France, similar principles in their production occupied the attention of English potters, and very highly-prized specimens of this ware, first manufactured at Chelsea, and afterwards at Derby, became the admiration of every connoisseur.

10. The biscuit of soft-paste porcelains is baked at a temperature much lower than the temperature used

for hard porcelains, and the glaze which coats it is extremely fusible, and very similar to that used for earthenwares. The vitreous quality of the paste, and the extreme fusibility of the glaze, give to these porcelains, more than to any other, the property of receiving beautiful designs on their surface. Colours in penetrating the glaze, acquire a great degree of brilliancy, without losing anything of their truthfulness. Indeed, the Sèvres porcelains exhibit for this reason several colours, which can only be imitated with great difficulty on other porcelain wares. Soft-paste porcelains are consequently the most valuable and the most prized of all potteries at the present day.

11. English porcelain differs materially from the two preceding porcelain wares. Its transparency is attained by combining with its paste a large quantity of bones calcined and ground down. Its other elements are infusible kaolin and granite. Calcined bones contain a large quantity of phosphate of lime, and though infusible alone, when they are combined with other clays, under the influence of heat, they acquire the property of a white enamel which, infused in a mass of earthy substances, produces a beautiful transparency. As this pottery contains but a very small portion of alumina, it is inferior in use, at least for those wares intended for exposure to fire, but its translucidity is finer, or at least whiter than that of other porcelains. Its glaze is similar to that of the earthenwares formerly in use, but is much harder. It is, however, sufficiently soft to enable the various colours placed on its surface to acquire a great degree of brilliancy. This kind of porcelain, now extensively used in England, was first manufactured at Worcester. North Staffordshire is, however, the principal centre of the English potteries at the present day.

12. Such are the principal characters which distinguish the various kinds of potteries manufactured hitherto. There still remains a great number of wares which differ in some respects from those which we have examined, not sufficiently so, however, to preclude their classification from among the processes we have described.—LOUIS ARNOUX.—*Translated by* C. J. DELILLE.

Natural Philosophy.

LESSON I.

UNDULATORY MOTION.

BY JOHN TYNDALL.

1. THERE are few things more pleasant than to stand by the sea on a stormy day, and to watch the billows advancing and breaking in foam upon the shore. Looking at the agitated ocean we observe a swell at a distance, which comes nearer and nearer, increasing apparently in height as it approaches; the side of the wave next the shore becomes more steep, the crest leans forward, overlaps and falls, sending its foam and spray high up the beach. When we follow the course of a wave in this manner we can hardly resist the belief that the water itself is moving forward; there appears to be a manifest motion from the ocean towards the shore; but if our spectator be an observant boy, he will soon learn that the motion of the *wave* is very different from the motion of the *water*. He watches a sea-bird floating securely among the billows, sometimes he sees it lifted aloft and seated on the summit of a wave, while at the next moment the wave has passed under it and the fowl is in the trough between two waves: he naturally concludes that this could not be if the water were carried onward by the wave. When a boy, I took pleasure in swimming in a rough sea, and when weary with climbing the billows, it was my habit to turn and rest myself by floating. The advancing waves rocked me pleasantly up and down, but they did not carry me forward. This fact now helps me to understand the real nature of the motion which produces waves, and thus illustrates one of the characteristics of natural philosophy. By it the commonest acts of a boy are caused to furnish food for thought; they suggest problems by which his attention is engaged, his knowledge augmented, and his pleasures refined.

2. Let one end of a rope be fastened to a wall or post, and the other end taken in the hand. The rope being held loosely, give the hand a sudden jerk. An undulation will be observed to rush along the rope from the hand to

the other extremity, and by repeating the act, a series of waves may be caused to follow each other in succession. In this case it is manifest that although the waves move forward, the particles of the rope make short excursions to and fro in a direction at right angles to that in which the waves proceed. The case is almost exactly similar with the waves of the sea. If the *water* of the sea moved forward with the *wave*, a fowl seated on the crest of a billow would be carried along with it: the same would occur to a boat or ship; but the fact that both the fowl and the boat are merely affected by an up-and-down movement proves that the particles of water oscillate through a comparatively small space: strictly speaking, in ascending and descending, they move in curves more or less circular.

3. REFLECTION OF WAVES.—When a stone is cast into

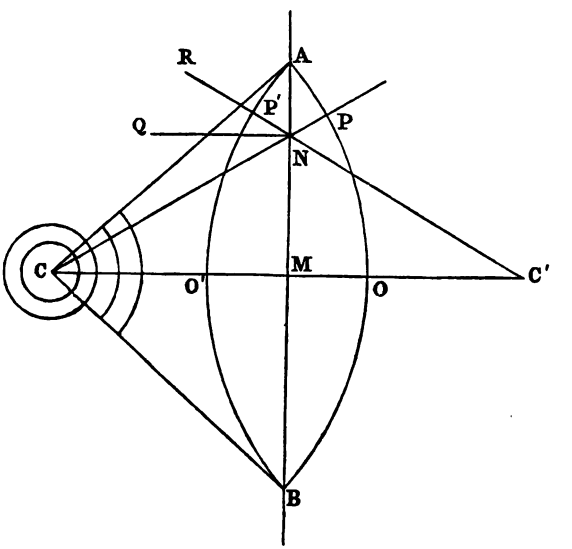


Fig. 1.

a tranquil lake a series of waves spread themselves round the point of disturbance. Supposing C (fig. 1) to be

the point thus disturbed, and that the waves propagate themselves to the wall A B, which forms the boundary of the lake. Each ring arrives at the point M of the wall first, and after a certain time it reaches the points A and B also. If no obstacle existed, the foremost part of the wave would reach the point O at the moment the points A and B are attained by the portions corresponding to them. On reaching the point M, however, the wave is reflected, and the ring thus sent back moves with the same velocity as the direct one; the consequence is, that the reflected wave will have reached the point O' in the same time that it would have taken to proceed to O. As each point of the wave successively meets the wall, reflection takes place, and the result is, that the sum of these reflections constitutes a wave A O' B whose centre is at C', as far behind the wall A B as the point C is before it.

4. Let any radius C P be drawn from the centre C to the circumference which the direct wave would have had if it could have proceeded forward; this radius cuts the wall at the point N. Through N let a second radius C' P' be drawn from the centre to the circumference of the reflected wave, and from the point N let a perpendicular N Q be erected to the wall A B. The angle C N Q, which the radius of the direct wave makes with this perpendicular is called the angle of incidence, while the angle R N Q, which the radius of the reflected wave makes with the same perpendicular, is called the angle of reflection. Every boy who knows a little of the first book of Euclid will be able to *prove* that the angle C N Q is equal to R N Q; and even a boy who does not know Euclid will, on reflection, be able to *see* that this is the case. We thus arrive at the important law—a law of the most extensive utility in physics—that *the angle of incidence of a wave is equal to the angle of reflection.* Supposing the wall A B to be a perfectly-hard obstacle, and that a boy shoots against it from the point C along the line C N a perfectly elastic marble, it also would be reflected along the line N R, the law of reflection of waves being the same as that of perfectly-elastic bodies.

5. REFLECTION FROM AN ELLIPSE.—No matter what the nature of the surface may be, whether curved or plain, this law holds good. There are two curves which possess a peculiar interest in reference to this law, and which we will therefore now describe. The first is the ellipse, which is constructed in the following manner: take two common pins, and with them fasten a sheet of paper to a table, the pins being at the points F F', say six inches asunder: take a string fourteen or fifteen inches in length, unite its ends and throw it over the pins: with the point of a pencil at P stretch the string, and while keeping it stretched let the pencil be carried round. The curve described by the point of the pencil is an ellipse.

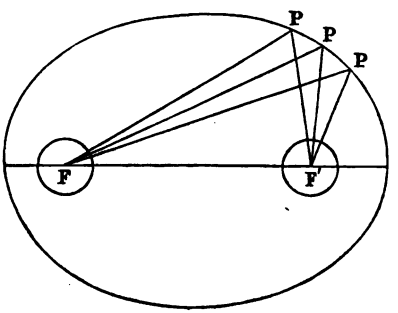


Fig. 2.

6. The points F F' are called the foci of the ellipse, and it is a property of the curve that two lines drawn from any point P to the foci make equal angles with the perpendicular to the curve at this point. If therefore we suppose a lake to be of the shape of an ellipse, and that a boy drops a stone into the focus F; the waves proceeding from this focus, when they strike the boundary of the lake at P, will be reflected in the direction P F' towards the second focus, and around the point F' will be formed a series of rings like those existing round the point F. This elegant experiment might be made on a small scale with mercury instead of water.

7. Reflection from a Parabola.—The second curve is the parabola, which differs from the ellipse in the circumstance that it is not what we call a closed curve: it does not return into itself, so as to enclose a space. The curve is sketched in fig. 3; it possesses a single focus F. The line V M is called the axis of the parabola, and the nature of the curve is such, that when we draw two lines from any point P in the curve, one to the focus F, and the other P p parallel to the axis V M,

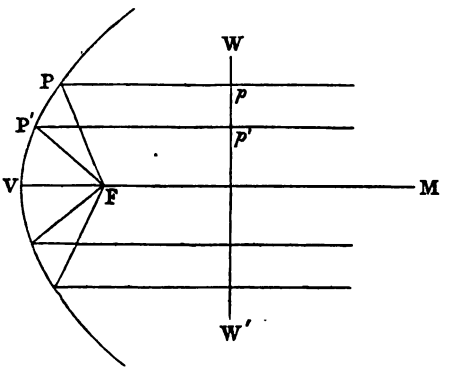


Fig. 3.

these two lines are equally inclined to a perpendicular at the point P. Hence if we suppose a portion of the boundary of a lake to be a parabolic curve, and a stone to be dropped into the lake at the focus, the waves proceeding from this point will be reflected in the direction of the line P p. Let W W' be a line drawn perpendicular to the axis V M, and let us inquire for an instant at what time the various portions of the reflected wave will reach this line. A second property of the parabola is that the two lines P F and P p, taken together, are always of the same length, no matter at what portions of the curve the point P may fall. Thus the sum of the two lines P F, P p is equal to the sum of the lines P' F, P'p' or to any other two drawn in a similar manner. The point of the wave reflected from P will

therefore reach the line W W' at precisely the same moment as the point of the wave reflected from P', for both of them have to travel over the same distance. The consequence is that the reflected wave will present the appearance of a straight line perpendicular to the axis of the parabola.

8. It is quite manifest that if we suppose the wave W W', instead of proceeding from the curve, to be moving towards it, it would, upon reflection from the surface, retrace its course, and form a circular wave around the focus F. Or, instead of supposing the wave thus to return upon its own footsteps, let a second parabolic reflector be placed in the path of the wave: the series of waves proceeding from the focus of the first reflector, will move forward in straight lines towards the second, and after reflection from it, they will collect themselves in rings around the focus of the second reflector. This arrangement of reflectors is shown in fig. 4.

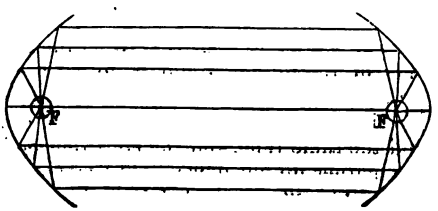


Fig. 4.

9. INTERFERENCE OF WAVES.—We now arrive at a point of great importance in wave motion, to which I will briefly direct your attention. Let A B and E D, (fig. 5, p. 244), be two branches of a canal which unite at F to form single channel F C. Let L be a lake which supplies the canals with water, and let a series of waves W W' advance along the lake towards the canals. Let these waves be supposed to enter A B and C D at the same moment; if the distance from A to F be perfectly equal to the distance from E to F, a particle of water at F will be lifted upwards or depressed downwards at the selfsame moment by the waves from both canals, and the consequence is that the distan

through which the water at F is lifted or depressed will be greater than if only one of the waves acted upon

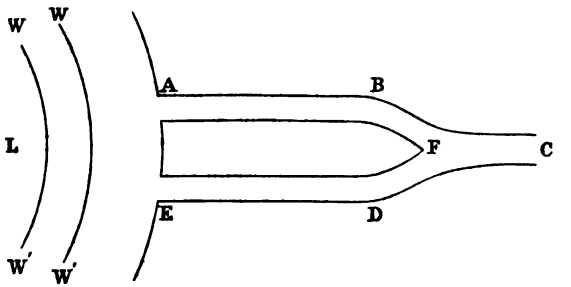


Fig. 6.

it. Let us now suppose that the two channels A B, E D are not of the same length, and that the difference in length is such that at the precise moment when the *elevations* of the waves from A B reach the point F, the *depressions* of the waves from E D reach the same point. The action of the former would be to *lift* the point F, while the effect of the latter would be to *depress* it: the point F is thus pushed upwards and pulled downwards at one and the same time, and the consequence is that it will move neither up nor down. The waves annihilate each other. The effects which I have thus endeavoured to describe are known under the name of *interference*. The principle of interference is one of the utmost importance in physics, and it will therefore be worth some trouble on your part to comprehend, as far as it is possible from this brief description, the nature of the principle.

10. On the Effects of Oil upon Water.—I think I may, without improperly wandering from the subject of the present article, say in this place, a few words on the remarkable influence of oil upon agitated water, as you will often find, in the works of poets especially, allusions to this subject, which might otherwise be unintelligible to you. Here is an example which just occurs to me:—

> "I pour on life's tempestuous sea
> The oil of peace with thoughts of thee."

The celebrated Benjamin Franklin was once informed by a friend, that the fishermen on the coast of Gibraltar, when they wished to make the surface of the sea smooth, and thus obtain light sufficient to enable them to see the large oysters at the bottom, were accustomed to pour oil upon the surface. On other parts of the Spanish coast the divers carry oil in their mouths, and when they want light they spurt it out; the oil ascends to the surface, spreads over it, and smooths down the ripples which interfere with the entrance of the light. Even in the case of shipwreck, oil has been used to still the water. Mr. Richter, who accompanied a Danish captain to Saint Thomas, stood, during a terrific storm, upon the coast of the island of Santo Porto, and witnessed the wreck and sinking of the ship which had carried him to the island. Immediately after the disappearance of the ship, its boat was observed in the middle of the bay, being driven towards the coast by the storm. When it reached the strand, the sea around the boat appeared to be tranquillized, as if by magic; the white foam disappeared from the surface, and all was still for an instant. Immediately afterwards, however, the billows reared their heads with redoubled force, and *without bursting into foam*, flung the boat high upon the strand. Some men sprang out of the boat, and ran up the beach in order to save themselves from being laid hold of by the succeeding wave. It had been the precaution of the captain to carry with him at all times a small cask of oil: this did excellent service in the present instance, and without it a successful landing would have been impossible; for, when the boat was about to be overwhelmed by the breakers at the edge of the bay, the cask was stove in, and the oil poured upon the water—a sudden change of the surface was thereby effected, which was observable from a considerable distance. The oil could not, indeed, render the waves still, but it prevented them from being converted into breakers, and caused them to roll up the beach, carrying the boat along with them to such a distance that its crew were enabled to escape.

11. If you place a piece of silk cloth upon a smooth

table, and push the cloth obliquely with your finger, the cloth yields, and glides over the table, which is thus in a great measure relieved from the effect of the push. So also when water is covered by a layer of oil, which does not cling to it, the oil, acted upon by the wind, glides over the surface of the water, and thus lessens the action of the wind upon the surface. It is true that oil cannot level down the larger waves when they have been once formed, but the sides of large waves are always ridged and furrowed by smaller waves, which render the large ones rough, and thus enables the wind to act upon them with greater power. The oil hinders the formation of these smaller ripples, and by thus lessening the friction it diminishes the effect of the wind. Franklin made some experiments on the effect of oil upon the ponds on Clapham Common. Choosing a time when the surface was ruffled by the wind, he first poured a little oil upon that side of the pond *towards* which the wind blew across the water. Here the waves were largest; but the oil had no effect in rendering the surface smooth. He next went to that side of the pond *from* which the wind blew, and poured a quantity of oil, not exceeding a teaspoonful, upon the surface, which immediately became tranquil for a space of several square yards. This tranquil space extended itself in an astonishing manner, and spread gradually, until it reached the opposite bank of the pond; and thus a surface of half an acre was rendered as smooth as a mirror. On a small scale, Franklin's experiments appeared all to succeed; an experiment, however, which he made on the sea-coast near Portsmouth in 1773 was not attended with equal success.

LESSON II.

SOUND.

1. WHILE I write these lines the sound of a piano reaches my ear. I hear notes of different kinds, some high, some low, some discordant—for the performer is a boy—and some blending together so as to produce a pleasing harmony. How do these sounds travel from

the piano to me? Why is it that one note is shrill and another deep? Why do one pair of sounds unite to produce harmony while another pair united together produce discord? Surely here is a subject worthy of our efforts to understand it. We will approach it carefully and by easy degrees.

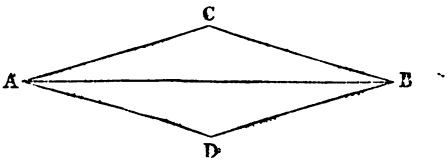


Fig. 6.

2. VIBRATION OF A STRING.—Let us suppose an elastic string to be stretched between the points A and B, fig. 6. The line A B is the position of equilibrium of the string, or that position in which it will rest, if left to itself. Let the string be taken in the fingers, forcibly drawn aside to C and then let loose: it will instantly return towards its position of equilibrium, but when it reaches it, it will not stop there. On coming towards the position A B, it has acquired a certain velocity, and on account of its inertia, will pass A B and go on to D at the other side of it. From D it will return again towards C, and thus execute a series of vibrations before it finally comes to rest. The principle is exactly the same as that of the pendulum. If you draw a pendulum aside from the vertical line in which it hangs, and let it go, it will not only return to its position of equilibrium, but will swing beyond it, and will continue so to swing until it is arrested by the friction of the air, or by that of its points of support.

3. COMMUNICATION OF MOTION TO THE ATMOSPHERE.—A string cannot, however, vibrate in our atmosphere in the manner indicated without communicating its motion to the air around it. When the string passes swiftly from C towards D it presses the particles of air in the direction of D more closely together; and on the contrary, when the string recedes from D to C, its effect is to leave the space behind it in some measure

deprived of air. So that the total effect of the string upon the atmosphere is to produce in quick succession condensations and rarefactions of the air.

4. Now, the sound of such a string travels on a frosty day at the rate of 1086 feet in a second. Is it then to be supposed that the air struck by the string is driven over so great a space in so short a time? By no means. We have here a case quite similar to that of waves in water: the particles of air, like the particles of water, make only short excursions to and fro. Sometimes they approach each other, and are for an instant crowded together; they then recede from each other to a certain distance, then close up again, then recede, and so on; the oscillations of each individual particle being thus confined within very narrow bounds.

5. Not so, however, with the undulatory motion of the air thus produced. As the undulations run along a rope when it is shaken by the hand, so each condensation produced by the string moves forward through the air, and is followed by a rarefaction; these are followed by a second and a third condensation and rarefaction, and this effect continues to be produced as long as the string continues to vibrate. One difference, however, exists between the motion of the rope and the motion of the air; the particles of the former oscillate at right angles to the direction of the wave, while the particles of the latter move to and fro in the direction in which the wave is moving. Along the line in which the motion of the vibrating string is propagated we have, therefore, a state of things which may be represented by fig. 7.

Fig. 7.

Here the portions where the lines are far apart are meant to represent the spaces where the air is rarefied, while the packing of the lines closely together is meant to show the condensed portions of the air. In the case of water a ridge and its adjacent depression constitute a

wave; in the case of the undulations, which we are now considering, a condensation and its accompanying rarefaction constitute a wave. In the case of water the length of a wave is the distance between two adjacent summits or furrows; in the present case the length of a wave is expressed by the distance from the centre of one condensation or rarefaction to the centre of the preceding or succeeding one. There are, therefore, three complete waves shown in fig. 7.

6. Effect of Undulations upon the Ear.—Supposing a stretched membrane—the head of a drum for example—to be placed at B. The waves of air proceeding from a vibrating string, situated in the direction of A, will strike upon the membrane, and throw it into a state of vibration. Now, within the human ear, and drawn across the passage which leads to the brain, there is stretched a tremulous membrane called the *tympanum*, or drum of the ear, from its resemblance to the instrument just referred to. This receives the shocks of the waves of air, transmits them through an appropriate nerve to the brain, and in this way the sensation of sound is excited.

7. On Melody, Pitch, and Harmony.—The famous philosopher Galileo, to whom we have already referred, was once passing through the cathedral of Pisa, when his attention was arrested by a suspended lamp which had been set swinging by the wind, or by some other cause. He observed, as the lamp swung less and less widely, that the time which it required to perform a swing remained the same: an oscillation of short length, or *amplitude*, as it is called, required as much time for its performance as a long one. Reflecting upon this, he was led to the invention of the pendulum as a means of measuring time. The swing upon the playground is a capital instrument for verifying the observation of Galileo. Let a boy swing to and fro through the space of one foot, he will find that this occupies just as much time as when he swings through ten times the distance; at least, the difference of time is too small to be noticed. Now this is exactly the case with our vibrating string; its oscillations become less and less wide, or, in the

language of science, the amplitude of the oscillations diminishes; but it requires the same time to perform a small oscillation as a large one. Hence the waves which it produces are all of the same length; they follow each other at a fixed interval of time, and communicate to the tympanum a regular succession of impulses. The regularity of these impulses produces a *musical sound*—it is the physical cause of melody.

8. This is a very beautiful result, but we will unravel the subject still further. A short string vibrates more quickly than a long one; a light string vibrates more quickly than a heavy one; consequently, by using strings of different lengths or of different thicknesses, we can produce sonorous waves of different lengths. What is the effect upon the ear? It is this; the short waves produce a shriller sound than the long ones. If a string four feet in length be cut in two halves, each half, when it vibrates, will send out twice as many waves in a second as are despatched by the entire string; the note produced by the short string in this case is the *octave* of that produced by the long one. The sole physical difference between a note and its octave is that, in the production of the former, only half the number of impulses reach the ear in a second as are necessary to produce the latter.

9. THE GAMUT; THE MONOCHORD.—We will now examine a little more closely the nature of those tones which come into application in music. The seven successive notes of the gamut may be expressed in musical symbols as follows:—

10. There is an instrument which enables us to tell the lengths of the strings which produce these various notes: this is called a monochord, and is sketched in fig. 8. A string of catgut, or wire, is attached to the fixed point *e*, and supported by two bridges at *f* and *h*; the string passes over a pulley *m*, and is stretched by a weight *p*. Under the string is a hollow sounding-

board, which serves to increase the intensity of the notes; the bridge *f* is moveable, so that by causing it to approach or recede from the fixed bridge *h*, any required length of string may be thrown into vibration.

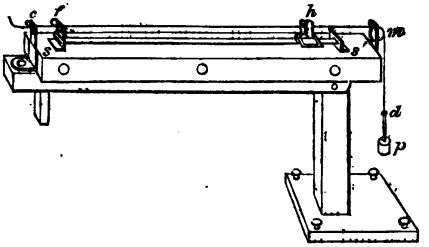


Fig. 8.

11. By means of this instrument let the first note C of the gamut be sounded, and then let the string be shortened until the note D is produced; on measuring the string which produces D we find that its length is $\frac{8}{9}$ths of that which produces the fundamental note C. Let the string be now shortened until the note E is produced; the length of string which produces this note will be found to be $\frac{4}{5}$ths of that which produces C. Shortening the string further, we find that the length which produces the note F is $\frac{3}{4}$ths of that which produces C. In the same way we learn that G is produced by $\frac{2}{3}$rds, A by $\frac{3}{5}$ths, and B by $\frac{8}{15}$ths of the length which produces the note C. Finally, we should find that the second C in the series is produced by a string whose length is one half of that corresponding to the fundamental note: the second C is the octave of the first.

12. Calling then the length of string which produces the fundamental note C, unity, the lengths which correspond to the seven notes of the gamut are expressed as follows:—

C	D	E	F	G	A	B	C
1	$\frac{8}{9}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{8}{15}$	$\frac{1}{2}$

Now it is a law of musical vibration that the number of vibrations performed in a given time increases exactly in proportion as the length of the string diminishes·

or, in other words, the number of vibrations is inversely proportional to the length of the string. Hence, if the number of vibrations corresponding to the fundamental note C be expressed by unity, by simply inverting the above fractions we obtain the proportionate vibrations corresponding to the seven notes of the gamut, viz:—

C	D	E	F	G	A	B	C
1	$\frac{8}{9}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{15}{8}$	2

13. These numbers simply express the *proportion* which the vibrations corresponding to the various notes bear to each other. It is manifest that if, instead of expressing the number of vibrations corresponding to the fundamental note C by 1 we express it by 8, the numbers corresponding to the other notes must be increased in the same proportion. The octave, for example, would then be 16 instead of 2; the note E would be 10 instead of $\frac{4}{5}$ths, and so on. By multiplying the whole series by 24, or in other words by expressing the number of vibrations corresponding to the first C by 24, we clear the series entirely of fractions, and find the following numbers as expressive of the vibrations necessary to produce the seven respective notes of the gamut:—

C	D	E	F	G	A	B	C
24	27	30	32	36	40	45	48

The second C, as we have stated, is the octave of the first: should it be required to find the number of vibrations corresponding to the octaves of the other notes, we should simply have to multiply the number of vibrations corresponding to each of those notes by 2. Thus 54 would be the number answering to the octave of D; 60 would answer to the octave of E, and so on.

If, therefore, in any given time the string producing the fundamental note C, make 24 vibrations; the string producing the note D will make 27; that producing the note E will make 30; that producing F, 32; that producing G, 36; that producing A, 40; that producing B, 45, and that producing the octave C, 48 in the same time.

14. But why are these particular notes chosen for the gamut? The answer is, that in combination they produce the most pleasant impressions upon the ear: this leads us to consider what it is that makes one pair of notes harmonious, and another pair discordant.

If we inquire which are the notes that sounded simultaneously with the fundamental note C will produce the most agreeable sensation, we shall find them to stand in the following order:—

First, the octave, which makes the most perfect harmony: this impression is produced by two series of waves, each wave of one series being twice the length of the other. Every second wave of the octave strikes the ear at the same moment as the wave from the fundamental note C.

Secondly, the fifth; this is produced when the fundamental note C is sounded with G. By reference to the row of proportionate vibrations, at paragraph 12, it will be seen that three vibrations of G are performed in the same time as two of C. Hence a wave from G enters the ear with every second one from C.

The next harmony is that of the fourth, which is produced when C and F are sounded together. By reference to the proportionate vibrations, we find that four of F's vibrations are executed in the same time as three of C's. Here therefore we have a coincident vibration at the commencement of every third vibration of the fundamental note C.

The harmony next to the fourth is that of the third, which is due to the simultaneous sounding of the notes C and E. Referring again to paragraph 12, we find that for every four vibrations of C we have five of E. The coincidences in this case are therefore at every fourth vibration of the fundamental note.

15. Thus we find the two facts constantly accompanying each other: the more frequent the coincidences the more perfect the harmony, and hence it is fair to infer, that these coincidences in vibrations are the true physical cause of harmony. When the coincidences become less and less frequent we soon merge into discord, and where a number of waves of differ-

lengths strike in an irregular and confused manner upon the ear, the impression of harmony is completely destroyed, and we are sensible of mere *noise*.

16. Interference of Sound.—We have already referred to the *interference* of waves formed in water, and a little reflection enables us to conceive of the possibility of two waves of air encountering each other so that they shall mutually destroy each other. Let us suppose the condensed portion of one wave and the rarefied portion of another to reach the same spot at the same moment. During condensation the direction of the motion of the particles of air is opposed to that during rarefaction, hence the possibility that while one wave may tend to cause the particles to *close up*, a second wave may tend to cause the same particles to *open out*, and that acted upon by these two opposing forces the motion of the particles may be quite destroyed. Each of the waves taken separately would produce sound, but acting together they produce none, and thus we arrive at the singular conclusion that by adding sound to sound we can produce silence. It is worthy of remark that a similar effect can be obtained with rays of light; by adding light to light it is possible to produce darkness. This fact has led to the modern belief that light is caused by undulations, and not, as Newton supposed it to be, by the darting off of little particles from the luminous body. Recent investigations have proved that a similar result can be obtained with the rays of heat; by adding heat to heat it is possible to produce cold, and this fact among others has led philosophers to believe that radiant heat is also the product of undulatory motion.

LESSON III.

1. Modes of determining the absolute Number of Vibrations of Musical Notes.—We have thus far confined ourselves to the consideration of the proportion which the vibrations corresponding to the seven notes of the gamut bear to each other. But supposing that we hear a certain tone—the shrill voice of an opera singer, for example—is there any means by which we

can ascertain the absolute number of vibrations to which this tone is due? Can we by any mechanical means count the number of impulses imparted by the vocal organs of the singer to the atmosphere in a second of time? We can. Let a strong wooden disk about seven inches in diameter be weighted by a coating of lead, and upon this disk let a second disk of thin pasteboard, a foot in diameter, be placed. Let the rim of the latter disk be pierced with round holes, each about two lines in diameter, and exactly the same distance apart all round: the disk thus prepared will present the appearance shown by fig. 10. Let this disk be placed upon the vertical axis of a whirling-table and caused to rotate. Let a glass tube of a diameter somewhat less than that of the holes in the pasteboard be so fixed that when the disk rotates the holes shall pass one after another exactly underneath the end of the glass tube. Supposing now that a person blows constantly through the glass tube, and that the number of holes in the disk is twenty, it is manifest that every time the disk goes once round twenty puffs will escape through the apertures. By causing the disk to revolve quickly, a musical note will soon be heard, which increases in height as the disk increases in velocity. Let the singer whose voice it is our intention to examine be placed near the instrument, and let the velocity of the disk be augmented until it sounds the same note as that sounded by the singer. The number of impulses imparted by both to the air will then be the same, and knowing the number of times the handle of the whirling-table is turned in a second, we can readily calculate the number of vibrations.

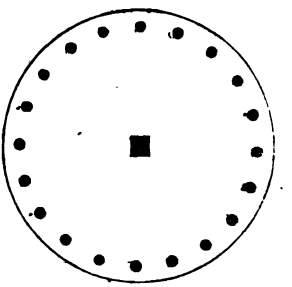


Fig. 10.

Suppose, for example, that the disk when brought to the pitch of the voice, makes one hundred revolutions

in a second: for each revolution we have twenty impulses, and consequently one hundred times twenty, or two thousand impulses in a second, will be the number produced by the singer.

In like manner if we compare the sound of our rotating disk with that of a vibrating, string we shall find that if a string, which produces a certain note be cut in two, to produce the note of the half string the disk must move with twice the velocity necessary to produce the note emitted from the whole string. If our disk be furnished with a second series of holes ten in number, and the note produced by blowing a stream of air against the series of ten, be compared with that produced by blowing against the series of twenty, it will be found that the latter note is the octave of the former.

2. The Syren.—This simple description will render plain to you the principle of a very beautiful instrument called the Syren, which was devised many years ago by a French philosopher, named Cagniard de la Tour. A circular brass vessel, *ff'* (fig. 11), is closed at the top by a smooth plate *v v'*: from the bottom of the vessel issues a tube *y y'*, through which air can be forced from suitable bellows into the vessel *ff'*. The plate *v v'* which covers the vessel is perforated with holes near its circumference. Above this plate is another, *u u'*, which is supported with such delicacy that the least impulse causes it to rotate. This plate is also pierced with the same number of holes as the under one, but, instead of being drilled perpendicularly through the plate, they are cut through it obliquely. A plan and section of the plate are given in fig. 12. Supposing the holes in the upper plate to coincide with those of the under one, the air from the bellows will be forced through: but in passing through the oblique holes it

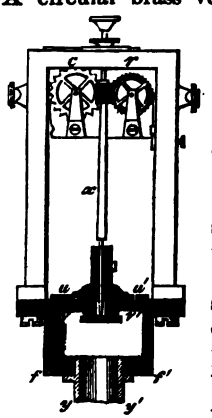


Fig. 11.

is manifest that part of its force will be expended in causing the upper plate to rotate, and by this artifice the plate is set in motion without a whirling-table or any other special apparatus. As the upper plate rotates, the air from the vessel beneath is alternately cut off and permitted to escape; when the holes below coincide with those above a puff escapes, but when they do not

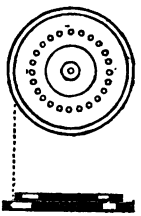


Fig. 12.

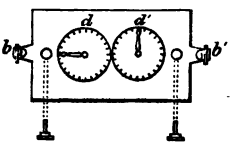


Fig. 13.

coincide the current is interrupted. The puffs thus escaping create undulations in the air, and when these are quick enough they produce a musical sound. By a little tact with the bellows the motion of the upper disk can be preserved uniform, and then we have a uniform note; by working the bellows vigorously, the velocity of the upper disk is increased and the note heightened.

Connected with the disk, and rotating along with it, is an axis x, and on this axis is a worm or endless screw, which imparts motion to a little clock-work mechanism above, and causes the toothed wheels c and r to rotate. Attached to the axes of these wheels are two indexes or hands which move over dials, such as are shown in fig. 13: one dial tells us the number of single revolutions, while the index of the other wheel moves forward one division every time a hunded revolutions are accomplished. Hence supposing after the lapse of a second's rotation the index of the latter dial stands at the number 5, and that of the former at the number 20, we should know the number of revolutions accomplished in a second to be 520, and multiplying this number by the number of perforations in the disk, we obtain the number of waves despatched by the disk in a second. This instrument has been recently modified by M. Dove.

of Berlin: one at present in my possession has four series of apertures. The series nearest the centre has eight holes, that nearest the circumference sixteen, the other two have ten and twelve apertures respectively. When the disk is in motion the outer series sounds the octave of the inner one, C, while the notes sounded by the other two series are those marked E and G in the gamut.

3. Supposing one hole only to be in the under plate, and that only one series of holes are used, we should have a case exactly similar to that first described, where a single stream of air from a glass tube was projected against a pasteboard disk. This single hole would produce the same note as that produced when the number of perforations in the lower plate is equal to that in the upper one. But the sound would not be at all so intense: by letting a puff escape from ten or twelve holes at the same time its action upon the ear is much more powerful than could be produced by the puff from a single aperture. I must warn you here against confounding *pitch* and *intensity*: the pitch depends solely upon the *number* of the puffs; while the intensity depends purely upon the *force* of the puffs. When all the holes in the upper disk correspond to those in the under one, the issue of air through all must be regarded as a *single puff*. The multiplication of the holes of the under disk increases the force of the puff, but as it does not increase the number of puffs, the pitch is just the same as if only a single aperture were used.

4. There is still another instrument made use of to determine the number of vibrations due to any particular note. It is based on the principle that a succession of taps, if they follow each other with sufficient rapidity, unite together to form a musical note. The instrument is sketched in fig. 14: *a a* is a solid frame which supports the large wheel *b*; from this wheel motion is communicated by a band *x*, to a toothed wheel *d'*. The teeth of the latter are caused to strike against a piece of card or other suitable substance. The successive shocks given to the card are imparted by it to the atmosphere, and when the velocity of the wheel *d'* is small, a succession of taps merely is audible.

When, however, the velocity increases, the taps appear to unite together and produce a continuous note, the

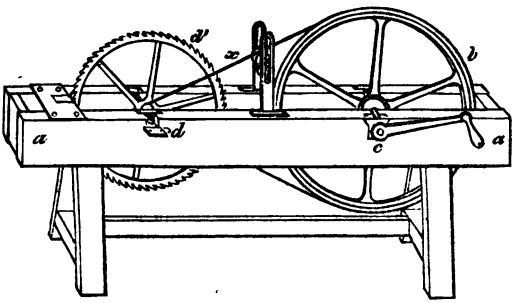
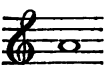


Fig. 14.

pitch of which is determined by the rapidity with which the card is struck by the teeth of the wheel. When we know the number of times the handle has gone round in a second, and also the number of teeth in the wheel d', we can readily calculate the number of taps given to the card in a second of time. With either this instrument or that of Cagniard de la Tour we can produce a note of the same pitch as that produced by a musquito, a gnat, a bee, or a beetle, and thus infer with the greatest accuracy the number of times that the insect claps its wings in a second.

5. By experiments with these instruments it has been ascertained that the lower A of the treble clef, written thus by musicians,  is produced by vibrations whose rate of production is 440 in a second. Knowing the number of vibrations performed in a second, it is very easy to calculate the length of the corresponding waves of air. We know, for example, that in a second of time, sound passes over a space of 1120 feet, hence, in the case of a string which vibrates say 440 times in a second, at the moment when the string makes its 440th vibration, the first wave is already 1120 feet distant; in the space therefore of 1120 feet, 440 waves must exist, and hence to find the length of one wave we must divide 1120 by 440, and find the quotient to be $2\frac{1}{2}$ feet nearly. Again

let it be required to determine the length of the waves produced by a gnat which flaps its wings 13,000 times a second. Here in the space of 1120 feet we have 13,000 waves. Reducing the feet to inches, and dividing by 13,000, it will be found that the length of each of these waves would be one inch nearly.

6. There is a tone which marks the limit of the power of the human ear, and beyond which its power of hearing fails; this limit is fixed at about 24,000 undulations per second; beyond this the sound becomes so thin and shrill that it vanishes altogether. It is perfectly possible however that there are animals possessing organs capable of appreciating sounds which are quite inaudible to human ears. To ascertain the number of vibrations corresponding to the deepest note of which the human ear is sensible, M. Savart devised the apparatus sketched in fig. 15. Here, instead of the toothed wheel d' in fig. 14, a single bar was caused to revolve, and at one point of its revolution it came very close to two plates of wood placed on opposite sides of it. It did not strike the plates of wood, but a minute interval, sometimes not more than the 8000th part of an inch, existed between the plates and the bar where it passed them. At the moment of its passage, however, a deafening sound was emitted; and when the velocity was slow, these explosions, for they might be called such, were heard in succession. But when a velocity was imparted to the bar sufficiently great to produce eight shocks a second, the sound became continuous, and a deep musical note was heard, of such intensity that it drowned all ordinary sounds. A note corresponding to eight impulses per second is the gravest of which the human ear has as yet been rendered sensible.

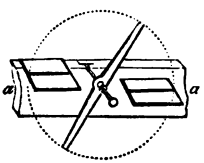


Fig. 15.

7. On the Reflection of Sound.—We have already learned that liquid waves striking against a surface are reflected according to a certain law: the same law holds strictly true of the waves of sound. This reflection is the cause of echoes. Supposing the air to be in

such a state that the velocity of sound is 1120 feet in a second; if a boy stand at 560 feet distance from a high wall and shout, the impulse travels through the air, is reflected from the wall, and reaches the ear as an echo, one second after the boy has shouted. I say one second, because the wave has had to travel first from the boy to the wall, and secondly from the wall back to the boy, in all a distance of 1120 feet. If instead of standing before a single wall, a boy stand between two walls, he will have an echo from each of them; if the boy stands midway between the walls, both echoes reach him at the same instant, but if nearer to one wall than to the other he hears the echoes in succession, the reflection from the distant wall reaching him latest. It is manifest that the wave proceeding from one of the walls may travel on to the other and be reflected there a second time, and that in this way echoes may be multiplied. Between the towns of Coblentz and Mayence the river Rhine makes its way between high precipitous cliffs. Between these cliffs an enchantress named the Lurlei is said in former ages to have sung, and by enticing vessels on to the rocks and shallows of the river, caused disastrous shipwrecks. Sometimes when the steamers from Rotterdam pass between these precipices, a man comes out of a little hut by the river side and fires a gun. The echoes sound from side to side like the rumbling of thunder, and at this place the echo has been found to be repeated seventeen times. There is a chasm among the Hartz mountains, where a gun is fired and a similar effect produced: in mountainous districts indeed this effect is very common. I once met a hunter on the Wengern Alp in Switzerland, right opposite to the Jungfrau mountain: he sounded an Alpine horn, and its sound, reflected from the sides of the mountains, returned to us, first strong, then by degrees feebler and softer, until finally it died away in delightful tones which resembled the notes of a flute sounding from the distant solitudes of snow. A single shepherd's boy, sitting on a crag and performing the so-called *Jodel*, can fill a ravine with the most wonderful melody, owing to the multiplication of echoes from the surrounding rocks and mountains.

8. If we speak through a tube, the sound, instead of diverging into the atmosphere, is reflected from the sides of the tube, and in this way a far greater body of sound may be sent to the ear than by the unaided voice. This is the philosophy of the speaking-trumpet. Gutta percha tubes are very much used at present to convey sounds from one portion of a building to another. Some time ago I stood near a friend in Manchester while he sent a whisper to a servant in the kitchen, which was twenty or thirty feet distant; the whisper was promptly responded to, although I, standing at a distance of three feet from my friend, heard nothing. The ear-trumpet presents a wide mouth to the rays of sound; while its narrow end is caused to enter the ear. In this way a greater number of these rays are collected by reflection than would otherwise reach the ear. In the whispering gallery of St. Paul's a speaker stands at one end of the diameter of the circular gallery while the person who hears stands at the opposite end with his ear to the wall. The wall is quite smooth and the whisper is reflected by it on both sides, the reflected impulses meeting at the point in which the hearer is placed. The law of reflection of waves of air is precisely the same as the law for liquid waves: the angle of incidence is equal to the angle of reflection. If a sound be produced at one focus of an elliptical reflector it will be collected together at the second focus. In like manner, if we make use of the pair of parabolic mirrors already described, the ticking of a watch placed in the focus of one mirror is distinctly heard at the focus of the other, while when the ear is drawn aside a little from the focus the ticking ceases to be audible.

9. Sound affected by the state of the Air.—If the air were cut away no sound would be possible; an explosion under the receiver of an air-pump is not heard unless the sound be transmitted through the solid parts of the pump. Even when the air is much rarefied the sound is much weakened. A man's voice on high mountain summits, where the air is thin, is feebler than the valleys; and the sound of a pistol fired by

Saussure on the summit of Mont Blanc was not louder than that of a common cracker. The intensity of the sound grows less as we ascend, but strange to say the velocity of sound on the tops of mountains is just the same as in the valleys. This of course is a mere puzzle when we do not understand it, but when it is understood it is very beautiful. It is, indeed, the character of science to confer beauty and interest upon facts which would otherwise possess no more value for us than for the dog or the horse. It would be far from wise to shut out the beauty which natural philosophy reveals to us, and to seek to restrict it to the satisfaction of those necessities which we possess in common with animals. Natural science, indeed, helps us to do the latter, but it does more, by appealing to faculties which man alone possesses, by exercising his intellect, and filling him with sweet joy, in the recognition of beauty and order in the creation.

The velocity of sound depends upon the elastic force of the air. Hot air is more elastic than cold, and hence, on a warm summer's day, sound travels more quickly than in winter. When the air is at a freezing temperature—that is, at a temperature of 0° on the centigrade, or of 32° on the Fahrenheit thermometer, the velocity of sound is, as before stated, 1086 feet a second. At a temperature of 10° C. or 50° Fahr., the velocity is nearly 1107 feet a second. The velocity of sound depends, however, not only upon the elastic force of the air, but also upon its weight. Fig. 16, upon the margin, is the same as that used to demonstrate the law of Marriotte, at page 317 of the Second Book of Lessons: referring to this page, you will be reminded, that when the air has been squeezed into half its bulk, it presses with a double force upon the sides of the tube whic

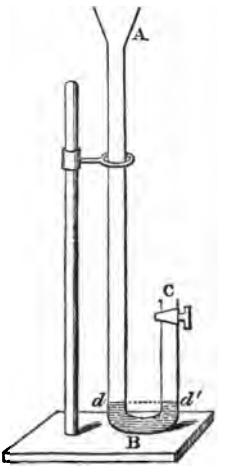


Fig. 16.

contains it; if it be reduced to one-third of its volume, it presses with a treble force against the sides of the tube, and the pressure thus exerted is a measure of the elastic force of the air. Now we have said that the more elastic air is, the more quickly will sound travel through it, and hence you might be disposed to conclude that sound, passing through this air, with its elasticity increased by pressure, will proceed at a higher velocity than through uncompressed air. But remember, that in this experiment we have done more than increase the *elasticity* of the air; we have also augmented its *density*, and we find that while the elastic force has become greater, the amount of matter to be set in motion has increased in precisely the same proportion. The additional weight exactly neutralises the additional elasticity, and sound will not, therefore, travel more quickly in such condensed air than in uncondensed. It is thus with the atmosphere, except when heat, which adds nothing to weight, is the cause of its increased elasticity. The elastic force at the surface of the sea is certainly greater than at the summit of a mountain; but the weight of the air is greater in the same proportion, and hence sound travels as quickly above as below.

10. Velocity of Sound in different Substances.—The velocity of sound is different in different substances. In alcohol its velocity at 10° C., or 50° Fahr., is 3796 feet in a second; in water of the same temperature it is 4767 feet a second, and in saturated water of ammonia it is no less than 6044 feet a second. In solid substances the velocity of sound is still higher: through mahogany and elm its velocity is upwards of 14 times its velocity in air; through iron and steel it travels with nearly 17 times its speed through air. If a boy place his ear at one end of a long beam of timber, while another boy scratches the opposite end with a nail or pin, it is surprising with what distinctness the sound will be heard. If one end of a long iron railing be struck with a hammer, an attentive boy standing at the other end will hear the sound of the stroke *twice*. The sound travels through the metal and through the air at the same time, but through the former it reaches the ear first, and this is the reason why the shock is heard double.

LESSON IV.

1. In conclusion, I will write down a few questions which will cause you to think on what I have written, and thus impress it upon your mind. In all the questions I will suppose the velocity of sound in air to be 1120 feet in a second.

Question 1.—The flash from a cannon fired from a vessel at Spithead is observed by a person on shore at precisely 3 o'clock in the afternoon; he hears the report at 1 minute 32 seconds past 3. What is the distance of the ship from the observer, the passage of light over this distance being supposed to be sensibly instantaneous?

Question 2.—The report of a gun fired in the dock-yard at Portsmouth reaches an object at Gosport 5200 feet distant, from which it is reflected at a right angle. The sound thus reflected reaches the ear of an observer standing 4 miles distant from the object; and who has previously heard the sound proceeding direct from the cannon. The direct sound being heard at noon, at what o'clock will the echo reach the observer?

Question 3.—An iron water-main, 3 miles long, receives a blow at one end; the shock is transmitted to the other, and then communicated to water, through which it is propagated for a distance of 2 miles: it afterwards passes through 1 mile of air to an observer: required the time of its passage from beginning to end?

2. To prepare you for some of the following questions, I must make you acquainted with certain important laws, which have been established by experiments made with the monochord described in paragraph 10, page 250.

a. When two strings of the same thickness and material, but of different lengths, are stretched by the same weight, the rates of vibration, as already stated, are inversely proportional to the length of the string.

b. Two strings of the same length and material, but of different thicknesses, being stretched by the same weight, the rates of vibration are inversely proportional to the diameters of the strings. If one string, for example, be three times as thick as the other, the number

of vibrations executed by the thick string in a second will be only one-third of the number executed by the thin one.

c. Two strings of the same length, material, and thickness, being stretched by different weights, the rates of vibration are directly proportional to the square root of the stretching force. Thus if one string be stretched by a force of 4 lbs. while the other is stretched by a force of 9 lbs., the rates of vibration of these two strings will be as the square root of 4 is to the square root of 9; or as 2 : 3.

Question 4.—A string 4 feet long, and stretched by a weight of 14 lbs., sends out 840 undulations in a second: to what length must we reduce this string, so that the number of undulations despatched in a second shall be 4620? This is solved by law *a*.

Question 5.—A string of catgut $\frac{1}{10}$th of an inch in thickness vibrates 964 times in a second: another string of the same length, and stretched by the same force, accomplishes 4820 vibrations in a second: required the diameter of the latter string? This is solved by law *b*.

Question 6.—Two strings of the same material and thickness, one 4 feet and the other 16 feet in length form successive monochords: the first is stretched by a weight of 12 lbs.: with what weight must the long one be stretched, so that both strings shall sound the same note? This is solved by law *c*.

Question 7.—Required the lengths of the waves corresponding to the lowest note of which the human ear is sensible: the rate of undulation being that stated in paragraph 6 page 260.

Question 8.—The length of the undulations produced by an insect's wing being three-quarters of an inch: it is required to calculate from this the number of times the insect flaps its wings in a second.

There is no difficulty in devising such questions as the foregoing; and they will be found a most instructive and entertaining exercise for the pupil.

JOHN TYNDALL.

Electricity and Magnetism.

LESSON I.

ELECTRICITY.

BY CHARLES V. WALKER.

1. INTIMATELY associated with all matter is a power or property, which in English might have been termed *Amberism;* for its existence was first noticed in connection with a piece of *amber*, that was being rubbed by the Milesian philosopher Thales, about 2450 years ago. From Electron, the Greek name of this substance, the property has been termed *Electricity*. Thales observed that light substances, in the neighbourhood of the rubbed amber, were animated with motion, and flew towards it. Many generations of men passed away; and, although this property of amber was more than once noticed, it still remained a solitary fact.

2. In the early centuries of the Christian era, the benumbing power of the torpedo—in fact, its power of giving what we now call *electric shocks*—was many times noticed. And, about 700 years ago, mention is made of a Gothic king, who emitted sparks from his own body. But in these early days, no connection was for a moment suspected to exist between these sparks and shocks; still less between them and the new powers given to amber by friction. And, when Dr. Gilbert, in the beginning of the 17th century, in his Treatise on Magnetism, took up the question of amber-attractions, all he did was to show that amber was not singular in the possession of this property; but that diamond, glass, sulphur, sealing-wax, and many other bodies, acquired by friction similar attractive powers; while other bodies, among which the metals were conspicuous, gave no evidence of having acquired them. Certain peculiarities, connected with these attractions, were observed and described in the course of the 17th century; but, about the latter end of this, and the beginning of the 18th century, sparks and snaps

as well as attractions, were obtained from bodies, that had undergone friction. These apparently dissimilar phenomena then began to be attributed to a common cause,—to the new properties, whatever they might be, that were developed in certain bodies by mere friction. The attention of philosophers was now greatly directed to these phenomena; and Electricity was numbered among the sciences. Facts rapidly accumulated; and in 1746, the first actual electric shock was obtained. This so corresponded with the numbing powers of the torpedo, by this time well known, that investigations were soon made; and the torpedo, the gymnotus, and a few other fishes, were found to have the power of producing electricity, which, Faraday, a few years ago, proved to be in all respects identical with electricity from other sources.

3. Franklin saw other analogies. He saw in the spark, the snap, and the shock, on the small scale, the true counterpart of the effects of a thunder-storm; and in 1752, he proved his proposition by drawing down electricity from a thunder-cloud, and collecting it in proper apparatus.

4. The 19th century was ushered in by the discovery that the mere arrangement in proper order of metals and liquids is another source of electricity; and so we had the *Voltaic pile*, one of the most important additions to physical science, of which we shall speak more hereafter.

Some relation had long been supposed to exist between electricity and magnetism; but of this no sufficient evidence could be obtained. And here we see how remarkably one discovery leads to another; with the Voltaic pile and a compass-needle before him, Œrsted, in 1807, discovered the true nature of this relation; and so laid the foundation of the important science of *Electro-magnetism;* and this became the stepping-stone to *Thermo-electricity;* for with Œrsted's fundamental fact before him, that a compass-needle points east and west, if electric force near it is moving north and south, Seebeck discovered, from the behaviour of his compass-needle, that when the equilibrium

of temperature between two metals was disturbed, electricity was produced.

5. Œrsted's discovery of the power, possessed by a Voltaic current of deflecting magnetic needles, was speedily followed by the discovery by Arago, that the same currents have power of imparting magnetism to iron, in fact, of *making magnets;*—and, if electricity produces magnetism, why, argued Faraday, should not magnetism produce electricity? He followed out this idea; and in 1831, he discovered that, by moving plates of metal or wires, in the presence of magnets, he could cause electric force to arise in the moving metal; and on this he founded the science of *Magneto-electricity.*

6. We thus find that there are several modes of obtaining electricity; and it has hence been distinguished into, FRICTIONAL,—VOLTAIC,—MAGNETO,—THERMO,—and ANIMAL, not on account of any inherent difference in the electricity produced, but as an indication rather of the means employed for producing it; for, no matter what the origin, it is identical in its nature, and, from whatever source obtained, has the property of causing *Shocks,—Deflections of Magnets,—Magnetization,—Spark,—Heat,—Chemical Action,*—and *Attraction.* Some of these effects are, it is true, developed in a more exalted degree by electricity, obtained by one method, than they are by that obtained by other methods; but still they are all, in each case, to be found by proper manipulation.

For instance, if a small stick of very good sealing-wax, not larger than the little finger, is rubbed two or three times along the sleeve of the coat, a *bright spark* may be drawn from it by the knuckle; but a feeble pricking, hardly perceptible, is all the *shock* that can be felt. On the other hand, if a gymnotus, or electric eel, is touched with both hands, the *shock* is most violent; but complicated apparatus and extreme care are necessary in order to obtain the feeblest *spark.*

7. Bodies present various facilities for the *transmission* of electric force; some offer little resistance to its passage, and have been called *conductors;* others offer great resistance, and have been called non-conductors,

or *insulators*: and lists have been drawn out, headed with silver, the best conductor, and terminating with shell-lac, the best insulator. A line is often drawn, as if to mark where conductors end and non-conductors begin. But no body is an absolute conductor or an absolute insulator; its position in the list is only relative. Under proper conditions, the very metals themselves, the best of all conductors, comport themselves as if they were insulators; and shell-lac and other bodies low on the list show themselves not altogether impervious to the passage of electricity. The air and gases rank high among insulators, but they give way under the presence of electricity of high tension, and a *disruptive discharge* occurs, as seen in the electric spark and in a flash of lightning. The same occurs with thin plates of glass, which, over and above any feeble power of conduction they may have, will break down if overcharged, and a discharge will occur through the fracture; and so with other bodies. The air will also discharge by *convection*. The dust and aqueous particles that float in it advance to the charged body, take a share of its electricity, and carry it away to discharge it elsewhere. When liquids, or solutions of bodies, act as conductors, they suffer *decomposition*; so much so that it was till very recently a question whether any true case had been proved of such conduction, unaccompanied by chemical decomposition in the conducting liquid.

8. Closely akin to this are the properties of certain compound bodies which, in their solid state, resist the passage of electricity, but which, when made liquid by heat, that is, when in a state of igneous fusion, take a high rank as conductors, with, however, the condition attached that, like liquids, they conduct at the expense of undergoing decomposition. For the most part, bodies, that conduct heat well, conduct electricity well; indeed, the lists for heat and electricity, with very few exceptions, follow the same order. Heat itself modifies the power of conducting electricity: in the case of liquids, it decreases the resistance opposed; but this is due to more causes than to its direct action,

for it facilitates the essentially-attendant decomposition, and in this way indirectly helps on the force. The conductibility of metals is diminished by heat. This is beautifully shown with a platinum wire, ignited to redness by the passage of an electric current. If one-half of the red part be immersed in cold water, the other half will become hotter, and rise to a white heat, returning to its original lower temperature, or to redness, when the other part, on being taken from the cold water, is allowed to become warmer; it is then a worse conductor, and so does not let enough electricity pass to produce white heat.

9. The *dimensions* of a body constitute an important element in its rank as a conductor; so that, by duly adjusting the sizes of two bodies, holding distant places in the list, may be obtained an equal amount of conducting power. A short length of the worse conductor is thus made equivalent to a long length of the better; a thick specimen of the worse conductor is found equal to a thin specimen of the better. Or, by comparing a very short with a very long length of the same conductor, an iron wire, for instance, the latter may be seen to acquire for the moment all the properties of a good non-conductor; a condition which presents itself on a large scale in telegraph wires, and which is essential to the well-being of the system.

10. To these differences in the properties of bodies are due all the processes and apparatus, by which we collect electricity, and all the instruments and arrangements by means of which we, on the one hand, study its effects, and, on the other, turn them to useful account. When a glass rod is rubbed with silk, it becomes active and attracts light bodies, as amber does; but, if there were no such property as *insulation*, its excitation would be lost as fast as it was produced; we should have no traces of its existence, and electricity would have remained undiscovered. Again, if there were no such property as *conduction*, or its equivalents, the rod once excited would remain so for ever, and we should never have known a state of electric equilibrium.

11. When electricity is about to move, that is, when an electric spark or single discharge, or an electric current or succession of discharges, is about to occur, the whole course through which it will move is, as it were, felt out before it; it makes no false steps. If, for instance, two conductors are before it, the one broken and discontinuous and the other perfect, it does not move along the discontinuous one till it discovers the flaw, and then return; but at once, and at the outset, it moves along the continuous one. So, again, if two conducting courses of different capacities are open before it, it does not take to this or that in any arbitrary manner or with any uncertainty; but, before the discharge begins, the whole operation is, as it were, measured out in proportions for each conductor; the quantity passing by each being in exact proportion to its conducting power in comparison with the other.

12. The property of electricity, by means of which this singular state of preparation is brought about, is termed *induction*. Nothing analogous to it is to be found elsewhere. It exists whether discharge takes place or not; and discharge is the consequence of induction acquiring a tension high enough to overcome the resistance, whatever it may be, whether small as in a good conductor, or great as in a good insulator.

Fig. 1 represents a set of brass balls, either hung from the ceiling by silk threads, or supported on a table by glass legs, of which one alone—the large one—is charged with electricity obtained from the friction of glass, which charge is represented by the sign +. Notwithstanding the other balls are at a distance off, and well insulated from the charged ball, they all become electrified by induction as long as the

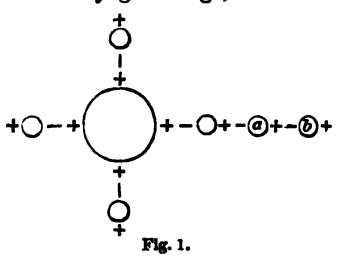


Fig. 1.

charged ball is there. And their outer sides, as shown by the signs +, exhibit electric states analogous to that of the charged ball; the nearer being more highly charged than the more distant. If a second series, of which one, *a*, only is shown, were outside the first, they also would have their natural equilibrium disturbed, and would in like manner exhibit, if properly examined, electric signs. If another, *b*, and another were added, the same would occur; and if a series terminated in the earth, and the balls, central one and all, were very close together, or actually touched, which constitutes a conductor, the central ball would be discharged. We have said that all the outer sides of the little balls show signs of electricity produced by the inductive action of the large ball; but a right examination would discover signs of electricity on their inner sides also. These latter states we have marked by the sign —; they are antagonistic to the other. The natural equilibrium of the bodies has been disturbed, and two distinct electric states have been produced. The outer side displays what we term positive, the inner side, what we term negative, electricity. When these electricities are combined, bodies are in a neutral state; but, whenever one of these electric states is displayed, an equivalent amount of the other must somewhere exist; and so, if our large ball were charged as before, and no small balls were present to show readily the counter charge on their inner sides, we could trace and, by proper management, find it even as far off as the walls of the room.

Non-conducting bodies, through which this property of induction occurs, have been termed *di-electrics*, from *dia*, through; and they have *specific* inductive powers: gum-lac, for instance, having twice the inductive power of air, and glass holding a much higher rank than air, but a little lower than lac.

LESSON II.

MEANS OF DEVELOPING ELECTRICITY.

1. Friction.—When a rod of glass is rubbed against silk, the electric equilibrium of both glass and silk is dis-

turbed, and each acquires electric properties, but they are antagonistic; what one has, so to speak, gained, the other has lost. If we call the glass positively electrized, or possessed of more than its due share of electricity, we find the silk possessed of less, or in a negative state. The silk may soon gather up all it has lost from the air and surrounding bodies; and the glass may, in like manner, part with all it has gained. If sealing-wax and glass are compared after similar rubbing, they are found antagonistic; the glass is positively charged and the sealing-wax negatively. Some bodies become negative with one rubber and positive with another. Cat's skin becomes positive with everything; sulphur becomes negative with everything.. Glass is made positive with cloth; negative with cat's skin.

2. The earth is the great reservoir of electricity; it supplies the want of negatively electrized bodies; it receives the excess of positively electrized, and so reduces either to a neutral state.

3. Although electricity is everywhere, it is not always manifest. It may be said to exist under four conditions. Its natural condition is a state of *equilibrium;* and to this state it is always tending to return, when disturbed. As such, it is ever present with us and about us. All things have their relative portion; and, although not the smallest change in place or condition can occur to anything, without interfering with this common order of things, the balance is, for the most part, so promptly adjusted, that we are rarely aware of what has taken place. Little, for instance, do we suspect that, in cutting a slice of meat, there may pass between the steel knife and the silver fork electricity enough to move the needle of a telegraph.

4. We next have *tension*, or static electricity; or, as we sometimes call it, *free* electricity. In this form we find it on a stick of sealing-wax or a rod of glass after they have been rubbed, or on the insulated bodies in fig. 1; and it so exists in the thunder-cloud. If a pile is made of zinc, copper, wet cloth, zinc, copper, wet cloth, many times repeated, the ends of the pile will exhibit feeble states of tension, one end being positive, the

other negative. Induction is the prime function of free electricity. The tendency of the dissimilar electricities, when free, or in a state of tension, to unite and neutralize each other, and so to escape from their constrained condition, is the true cause of the *attractions*, so early notices by Thales. They are not due, as might at first be supposed, to any mere attraction between the bodied themselves. If the small balls in fig. 1 are very light, and lightly suspended, the attraction of the negative electricity that is induced on their inner sides may be so great towards the positive charge of the larger ball, that they will fly to it; and, having touched it, they will take a charge from it and so become positively electrized; and now will recede and show *repulsion*, as far as the large ball is concerned, but attraction in respect to surrounding bodies.

5. This property, recession, is turned to account in the construction of *electroscopes* and *electrometers*. A pair of fine wires, or straws or gold leaves, according to the sensitiveness required, are suspended close together, insulated in a proper way, and protected from currents of air. Such an instrument will detect the presence of very small quantities of electricity; and, by the greater or less divergence of the leaves, will give some relative indication of the charge. If a pair of leaves in a state of repulsion are examined, the whole charge will be found on their outer sides and none on their inner: in like manner the whole charge is found on the surface of the large ball and none within. The charge acts by induction in all directions, and produces an equivalent of contrary electricity in surrounding matter; and the *attraction* of these contrary electricities, the one being on the surface of the leaves of the electroscope, and the other on distant bodies, is the real cause of the mutual recession of these and all other similarly electrized bodies; the *repulsion* is only apparent.

6. If a rod of metal be held very near to a positive and charged body, the near end of the rod will become negative; this will cause the near side of the ball to become more positive than before, at the expense of the far side, and a disruptive discharge, or the *electri*

spark will occur, the two contiguous contrary electricities will unite, and the body will be discharged.

7. *Dynamic* or *current* electricity is the third condition. This concerns its properties when in motion: in fact, during the act of discharge, whether violently, as with the spark just mentioned; or tranquilly, as when the two ends of the pile are connected with a wire. A spark may be regarded as a single element of a current; and a succession of sparks an imperfect approximation towards a current. But as the duration of a spark is infinitely small, and the time occupied in accumulating enough electricity to produce the next spark (small indeed though it be) is very great, compared with the duration of the spark, such an illustration of a current is most imperfect, the interruptions being beyond comparison greater than the durations. A six-inch electric spark passes in the 3000-millionth part of a second. But no electrical machine can supply the remotest approach to 3000 million such sparks per second; and the measure in which the number falls short of this is the measure of the discontinuity of the discharge, and of the degree, therefore, in which it falls short of being a true current.

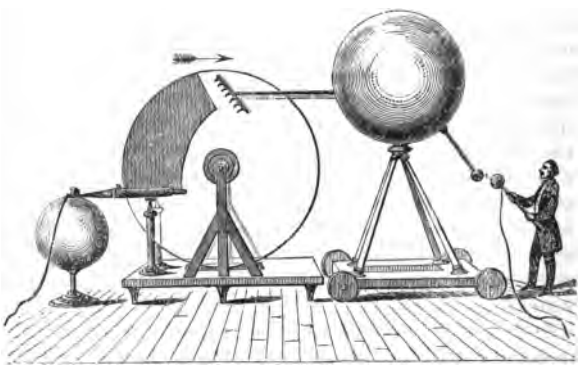


Fig. 2.

8. In illustration of this, let us refer to one of the largest electrical machines in the world, which is to be

found at the Polytechnic Institution in London, and of which a representation is given in fig. 2. It consists of a plate of glass 7 feet 3 inches in diameter, which is made to produce 80 revolutions in a minute, by steam-power, applied by means of a band coming from a shaft below and passing over a drum on the axis.

The rubbers are silk cushions, one on each side of the glass, and are seen at the left, mounted on glass legs. They are 3 inches wide, and 2 feet long; and thus act upon about 60 or 70 square feet of glass, which pass them 1½ times in a second; giving, in round numbers, about 90 square feet of glass, suffering friction in each second. But we can very easily *count* the six-inch sparks, as they are drawn off by the assistant on the right; and our powers of *counting* fall immeasurably below the number required to make the discharge continuous.

9. While this machine is before us, it will be convenient to point out how all its parts illustrate the properties of electricity. The rubber is connected to a metal globe on the left, which is itself connected with the earth by a wire; so that as fast as the rubber becomes negative, by friction, it is neutralized by discharging to the earth. When we wish to collect or examine the negative electricity, we remove the wire; and as the ball is upon an insulating glass stem, it retains a negative charge. The rubber is coated with an amalgam of mercury, zinc, and tin, which greatly increases the exciting power. The supports, on which the axis of the plate rests, are not necessarily insulators;—for the disc of glass, beyond the influence of the rubbers, has a radius of 19 inches, which well insulates the charge, and prevents its escape from the rubbed surfaces to the axis. The flap of silk, on the left side of the disc, prevents loss by *convection*. The large hollow metal globe to the right is called the prime conductor, and is 57 inches in diameter; it is insulated on glass legs;—its large size enables it to receive freely the great supplies of electricity furnished by the machine, from which it draws it off by the forks. Rods are fitted into the globe to direct the

charge to the apparatus that is in use. As the points on the fork collect, so would points on the conductor disperse; and hence in all apparatus for retaining charges of free electricity, sharp edges are avoided. The arrow shows the direction in which the plate rotates.

10. From the ball, with which the assistant is drawing off sparks, a wire may be seen leading to the ground. With a small machine, this is not needful; for the spark may be taken on the knuckles, and produces a mere pricking sensation; but one of the sparks from this large machine would knock a man down; and it is therefore necessary to allow them to pass off to the earth, without the assistant forming part of the circuit. The mere floor of the room is not sufficient to secure perfect discharge; it is necessary that the wires for this purpose shall lead to gas or water-pipes, or to some other equally-efficient discharging train. With a wire to the earth, there is no need for the ball in the assistant's hand to be mounted on a glass rod; for the small portion of the discharge that passes through him, when a good wire forms communication with the earth, is inappreciable.

Short sparks from the conductors of this machine follow each other with extreme rapidity, and far outstrip our power of counting, although they fall infinitely short of the continuity essential to a current.

11. Chemical Action.—Continuous currents of electricity are best obtained, by means of the chemical action that occurs between solid bodies and liquids, when arranged together in accordance with certain known conditions. These combinations may be made in a variety of ways, following in all cases a simple routine, of which fig. 3 is an illustration. If a plate of zinc and another of platinum are placed face to face, as in the figure, in a vessel of acid water, and are joined together by means of a wire, a current will pass along the

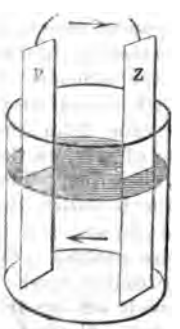


Fig. 3.

wire. If the wire is fine, and especially if it be of platinum, which is an indifferent conductor, it will become hot, visibly red or white, or even fused, according to the quantity of force in circulation. This is known as the *heating power* of electricity. The heating effects are equally obtained, if a quantity of sparks from the prime conductor of the electrical machine are accumulated, and then suddenly discharged through a fine wire. Short though the duration of such a discharge may be, its heating power has time enough to produce its effects. When the wire through which a current is passing is large, so as to present no serious resistance to the force in action, no sensible change occurs. Hence copper wires are often melted by lightning, but the copper rods, with which buildings, and the copper plates with which ships, are protected, being of large capacity, convey the discharge safely. We may easily connect the zinc and copper with a long large wire, that will present the same resistance as the shorter thin wire; and according to a fundamental law, which has been already mentioned, precisely the same amount of conductibility will then exist, or the same amount of resistance will be interposed, and hence the same amount of electricity circulate; but in the case of the large wire, no ignition would occur, for the force would be diffused over a large sectional area, and not concentrated in a small space as in the other. The arrow shows the direction in which the current of positive electricity circulates; and if the wires were cut asunder, and the ends examined, the end coming from the copper plate would give indications of being charged with electricity, similar to that obtained on rubbed glass; and the end from the zinc, with electricity similar to that obtained on rubbed sealing-wax; but these indications are extremely feeble, and could only be detected by the most delicate apparatus.

12. It will have been noticed that to procure small quantities of tension electricity, we rub a rod of glass against a piece of silk; and, for large quantities, we rub a plate of glass against silk with a little amalgam upon

it: in fact, we merely increase the size of the rubbed body, provide it with the best description of rubbers, and rub it effectually and rapidly, taking care, of course, to collect as fast as we produce. So also for current electricity;—if we wish to increase the quantity, we merely increase the size of the plates, and in some cases the size of the wire, other things being the same; and we find, as a natural consequence, that when little plates heat a given length of thin wire, large plates will heat the same length of thick wire.

Metals holding extreme positions in the series, and selected solutions, are employed in the production of useful currents of electricity; but feeble developments of current force occur in cases of innumerable juxtapositions of heterogeneous matter. There is a remarkable production of this force in living organization, which is most easily illustrated by taking portions of the legs of recently-killed frogs, and arranging them as in fig 4; when by delicate tests, it will be discovered that a feeble current is passing from the inner to the outer surface of the muscle, in each section, as shown by the arrow. The current exists during the life of the animal, and is found only in recently-killed muscle.

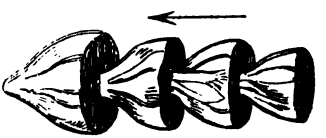


Fig. 4.

13. We have seen that a sensible time is required for the production of electricity by friction, though the time for its discharge is physically insensible. This is due to the very nature of friction itself; which, if closely analyzed, consists of nothing more than pressing two bodies into contact, and then separating them, not by mere lifting, but by dragging. When the great plate of glass rotates, the parts to be rubbed come successively to the cushion, are pressed, and pass on; but, if it were possible to rotate the plate at infinite speed, all other things remaining the same, the charge might be produced as rapidly as the discharge takes place.

A nearer approach to this occurs with the hydro-

electric machine, also at the Polytechnic Institution. It consists of a high-pressure tubular boiler, similar to that of a locomotive engine; the steam is allowed to discharge itself through a series of tubes terminating in jets mounted with hard wood; before it reaches the jets, some portion becomes condensed into aqueous vapour; these watery particles are carried onward with the steam, and are rubbed in rapid succession and with great violence against the wooden jets; they become positively electrized by the friction; and the jets, with the boiler of which they form part, and which is insulated on glass legs, become charged with very large quantities of negative electricity, the discharge of which is less discontinuous in its nature than that from the prime conductor of an ordinary electrical machine.

14. But, with a voltaic pair, the contacts and separations are of far more intimate character; they occur amongst the very molecules or chemical atoms of matter: the atoms that move, and the spaces through which they move, are infinitely small; the things to come into contact, and the spaces to be traversed in order to accomplish a contact and a separation, are as nothing in comparison with the tangible glass and silk of the electrical machine, and the measurable velocity of its rotation; and hence charge becomes as instantaneous as discharge, and we have the continuous current, for which we seek in vain, with the mere mechanical arrangements hitherto considered.

LESSON III.

VOLTAIC BATTERY.

1. We have said that when the plates of zinc and copper are in the acid water, and unconnected by a wire, they each exhibit signs of polar tension. The source of this is at the parts where the respective metals are in contact with the water. Water consists of two gases, oxygen and hydrogen. When the above arrangement is made, intimate contact occurs between the zinc and the oxygen of the first particles of water, and between the copper and the hydrogen of the last particles of water; and all the intermediate particles are thrown

into a state of polarization, the hydrogen of the first coming into intimate contact with the oxygen of the second, and ready, when the next condition is completed, to leave its own atom; and so on to the end of the series. The eight alternate circles in fig. 5 are to represent, the oxygen O, and the hydrogen H, of four atoms of water; and the two squares at either end, the zinc Z, and copper C, of a voltaic pair. The links above show the state of things when the water is in contact with the respective metals, but the metals are not connected together by the wires; that is, the various things in the cell are in *contact*, but nothing has yet occurred to cause any one to *separate* from any other. The signs + and − show the electric tension at this time of the ends of wires that come from the respective

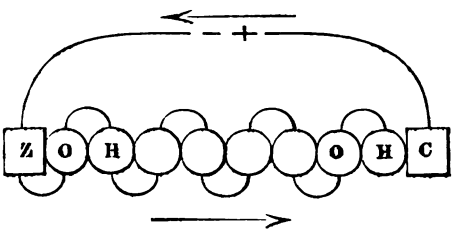


Fig. 5.

metals. But, when the wires are brought together, an electric discharge occurs between them, and, at the same time, an atom of zinc, Z, separates from the plate, and an atom of oxygen also separates from the first atom of water to combine with the atom of zinc; and an atom of hydrogen separates from the last atom of water at the copper plate, C, and rises free in the form of gas; and simultaneously with all this, the intermediate atoms of oxygen arrange themselves with those of hydrogen into atoms of water, as shown by the lower links. We have seen several things in contact with each other at the beginning of the operation, and electric tension appearing; and several separations to have been brought about at the end of the operation, and which are simultaneous with discharge and current.

2. The fuel, so to speak, that is here consumed, is, in the first instance, water and zinc; the products are hydrogen gas, which escapes, and oxide of zinc, that remains; the addition of a little sulphuric acid serves the double purpose of dissolving the oxide, as it is produced, and of making the water conduct the current better; for the same amount of current circulates through the liquid as through the wire—the arrow below, in figs. 3 and 5, showing the direction in the liquid, as the arrow above does its direction in the wire. It is very immaterial whether a current circulates, as in this case, in the liquid in which it is generated, or is generated elsewhere and sent through a liquid; in either case, the liquid or solution is compelled to render up its elements; in fact, to be decomposed.

3. The decomposing power of the voltaic current is irresistible; all compound bodies succumb before its silent but certain force. Many, that had long resisted all other forces, have readily yielded to this; and it has thus become, in the hands of the chemist, invaluable in difficult cases of analysis. The elements make their appearance according to very definite rules; and in this place or that, according to their rank in the lists that have been prepared. Oxygen, for instance, is always to be looked for at the place where the positive current enters the liquid, or at the zinc in the case before us. It is true that in this particular instance we cannot collect it; because, in its nascent state, it unites with the zinc, and is lost to us as soon as it is gained; but when a current enters a liquid by an unoxidizable metal, such as platinum, the oxygen must needs rise to the surface, for it has no affinity for that noble metal, and refuses to combine. Then, again, hydrogen and the metals are to be looked for at the spot where the current leaves the liquid; as at the copper in the case before us, where we find the hydrogen liberated in the form of gas: and this would be true, whether the current had left by other metals, as zinc; for unlike oxygen, hydrogen has no affinity for metals, and would still escape.

But it very frequently happens that, although hydrogen may not find in the metal plate anything with whic'

it has affinity, it may find it in the liquid itself. If a current passes through a liquid containing oxide of copper in solution, as, for instance, in the form of sulphate of copper, the hydrogen will still be liberated at its proper place, but instead of coming off as gas, it will be held back by a stronger attraction to the oxygen of the copper oxide, and the metal copper being deserted of its oxygen will make its appearance. This is called *secondary action*, and is the foundation of the art of electrotype; for the copper, as it is liberated, can be received on moulds, and come to us in any desired form. If the current passes through an aurous or an argentiferous solution, gold or silver will be released; and thus we have electro-gilding and electro-plating.

The apparatus is often so arranged, that, while a metal is in this way being extracted from the solution, the plate at the entering end shall be of the same metal; and matters may be so adjusted that some element in the solution, liberated there, shall combine with and dissolve this metal, just in proportion as it is extracted at the other side, and so keep up the strength of the solution. Occasionally, the plate, by which the current enters, is covered by varnish, with some design traced through and exposing the metal. In this case, the liberated element, say oxygen, can only combine with the exposed part of the metal, which thus becomes eroded, the rest remaining untouched; and so the design, whatever it may be, is etched. This is *electro-etching*.

4. The amount of activity displayed by a given voltaic pair depends on the amount of resistance opposed to the discharge; and hence the current of a feeble arrangement, if made to traverse only a short wire, will be equal to the current of a more powerful arrangement, that has to traverse a long wire. The *electro-motive* force of a pair of plates depends upon the metals and liquids employed. Of the ordinary metals zinc is at one end of the series of voltaic agents, and platinum and gold at the other; carbon will serve instead of platinum. Zinc with platinum and distilled water has very feeble electro-motive force; with acid water, the force is greater; with acid water about the

zinc, and sulphate of copper about the other metal (the liquids being kept apart by a wall of card, wood, or plaster), greater still—this is Daniell's battery; with strong sulphuric acid water about the zinc, and nitric acid about the platinum, very powerful—this is Grove's battery.

5. When a series of pairs, or voltaic pile or battery, is employed, and the amount of chemical decomposition manifested in any cell of the series is definite for a given current in a given time; and the same amount of decomposition occurs in each cell. So also if the current of a voltaic series be made to pass through any compound contained in a distinct cell, the decomposing power manifested in it will be equivalent to what is found in every battery cell. On this principle, the *Voltameter* has been constructed. Platinum wires or plates, connected with each end of the battery, are led into a vessel containing dilute sulphuric acid. Glass tubes filled with the acid solution are inverted over the platinum wires, so as to collect the gases liberated, and are graduated into cubic inches in order to afford comparative measures of quantity. When a current of electricity is passed through this apparatus, the water is decomposed, and oxygen gas given off at the positive wire and hydrogen at the negative: the quantity of gas collected in a given time in the tubes, indicates the relative quantity of current that has circulated.

6. When great resistance, exterior to the generating cell, is to be overcome, the current from a single pair of the best combination is valueless. We then multiply the pairs, in proportion to the amount of resistance to be overcome, taking care that the zinc of one cell is connected with the copper or other metal of the next. We increase the electro-motive force in direct proportion to the number of cells employed: it is true we also increase the resistance within the cells in direct proportion to the number added; but as this is only a portion of the resistance (the rest being in the circuit exterior to the battery), we obtain a real increase in the available force.

The tension of a voltaic battery increases with the number of plates; and a spark may be obtained between

the terminals of a very long series. The *electric light* is obtained from a moderate series of some of the most active combinations; the terminal wires are mounted with charcoal points; the striking distance, over which a spark will pass being inappreciable, for practical purposes, the points are touched to allow the current to circulate, and are then drawn apart to half an inch or so and held there, when an intense light is exhibited.

If the ends of a voltaic series be touched by the moistened hands, a warmish, numbing, tremulous sensation occurs: with a long series, this species of shock is very sensible, and convulses the muscles.

7. Current electricity has its own inductive effects, which are in some sort analogous to those of free electricity. If two wires be insulated from each other and parallel, and a voltaic current is passed through one, it will cause a current to arise in the other, and to have a reverse direction. But this induced current has only an instant of existence; it appears, as the primary current is made, and appears again, as the primary current ceases, but has no being during the intermediate time. To obtain it with the best effect, a moderate length of stout insulated copper wire is wound on a bobbin, and outside this a long length of very fine insulated copper wire. The primary current is thus many times repeated in the presence of the secondary wire. As the secondary current only occurs at the beginning and end of the primary, mechanical arrangements have been contrived for making and breaking contact with the battery, as rapidly as possible, so as to obtain many currents in a small space of time. The current when contact is broken has the greater tension; it appears as a bright spark, or if received through the body, is acutely severe.

If a wire, in which a continuous current is passing, be suddenly brought near to, and as suddenly withdrawn from, another wire, it will produce in it an induced current; for, as far as the secondary wire is concerned, the primary current as much originates in its neighbourhood and ceases by this process as by the other; the difference being that time is required for

mechanical approach and recession, and that the current has more of a progressive character.

8. The study of the mutual *attractions* and *repulsions* of currents is highly instructive. The fundamental law is, that two currents moving in the same direction in different wires attract each other; moving in reverse directions, repel each other. Out of this law arise many relations, depending on the relative directions of currents.

9. Electricity is very often dissimulated or *disguised;* and this is the last form under which it may be viewed. We are not prepared to say that it does not exist in this way in the interval of time between the initial and the final induced currents; that is, after the primary current has begun and before it ceases. The term is, however, applied to free electricity, which, under certain conditions, is as insensible as if none were there, and, for the time being, ceases to be free.

I have shown in fig. 1, that all the insulated balls about the central charged ball exhibit signs of polar tension, the outside signs corresponding with that of the charged ball. If now any one of these balls be touched, a spark may be drawn off from it, and it will no longer exhibit signs of being charged. If, when in this passive condition, it is carried away beyond the influence of the charged ball, it will be found charged with the contrary electricity,—negative, that is, if the centre ball be positive. It again ceases to give signs of charge on being restored to its original place. Its negative charge is *disguised* by the attraction of the positive charge of the other.

10. Not only does the charged body act in this way by induction, and produce an equivalent converse charge in bodies about it; but this converse charge reacts upon the original charge, and modifies it. By taking advantage of this full effect of induction, we have apparatus by which we can accumulate large quantities of electricity, to wit, the *Leyden Jar*, the elementary form of which is a flat sheet of glass, coated on either side up to a few inches of the edge with tinfoil. If the pane is held insulated by one corner, a few sparks only can be collected on one side from the prime con

ductor: the free electricity on the other side, arising from inductive polarization, reacts and produces a counter-polarization, so that similar electricities occupy the outer sides of each coating. If the other side is now touched, so that its free electricity escapes, this side becomes in reality negative; as such, it attracts the positive electricity of the original side towards the glass, and disguises it, so that very little of the original charge exists free. More sparks may now be added, and if the second side be kept in permanent communication with the ground, it will acquire a further negative charge up to a certain point, in proportion as a positive charge is given to the first side. There will now exist on the opposite sides a large quantity of the converse electricities, highly attracted towards each other through the glass, and so occupied with each other as to be, as we have termed it, *disguised*. If any flaw or weak place exists in the glass, these charges will soon throw off their disguise, and combine, by displacing and cracking the glass, just as a lightning-flash darts through the air in similar case.

11. There will always remain a little free electricity on one side. If, while the glass is held insulated, this side is touched, the free electricity will escape, and a little free charge will appear on the other side; and so, by touching the sides alternately, single sparks may be taken away, one by one, till the whole is discharged. If the sides are joined over, as it were, by touching one with each hand, the inductive action takes a new direction through this conducting channel, and the disguised electricity is discharged *en masse*, and we have the *electric shock*.

For practical purposes, jars, instead of plates of glass, are used; they are coated inside and out with tinfoil, leaving a belt of glass free of tinfoil, for the sake of insulation; a Leyden battery consists of several jars, having all the inside coatings connected, and all the outside, so as to represent, in fact, one large plate or jar.

12. The property of *induction* furnishes us with the *rophorus*, an instrument that, when once charged,

supplies an almost inexhaustible store of electricity. It consists of a plate of resin, and a metal cover with a glass handle. A mixture of rosin, shellac, and Venice turpentine, poured to the depth of half an inch in a tin dish, is the best resin plate;—brass makes a convenient cover. The disc of resin is rubbed with a cat's skin, and is thus electrized negatively. The greater part of this negative electricity attracts to itself positive on the under side of the resin, and both become disguised, and will remain so for months, or even years. If the cover is placed on, it becomes polarized, negative above, positive below, and a negative spark may be drawn. If it is now lifted up, a positive spark may be drawn from it; it may then be returned to its place and touched again; another negative spark may be drawn; when again lifted, another positive spark appears, and this may be repeated for an indefinite number of times.

We have thus briefly glanced at some of the most prominent features of electricity, without attempting to enter too minutely into details; and have in this way endeavoured to lay a foundation, upon which the industrious student may build.

LESSON IV.

MAGNETISM.

1. MAGNETISM.—Long antecedent to the commencement of the Christian era a ferruginous mineral substance was discovered, which had the property of attracting iron. It derives its name, according to general opinion, from Magnesia, a city in Lydia, where it was found. It consists of iron and oxygen, and is called by some chemists deutoxide of iron, by others ferroso-ferric oxide; it is called also *magnetic oxide* of iron. It contains two atoms of iron to three of oxygen.

Magnetic oxide of iron is popularly called *loadstone*, which serves as a convenient word to mark the distinction between the native magnetic oxide and the more perfect forms of artificial magnet. It may be formed artificially by certain chemical processes; but

in this case, although it has the same chemical composition as the native oxide, and is attracted by the magnet, it is not itself magnetized, or possessed of magnetic power. The material substratum, so to speak, is present, but the property which has been called *magnetism* is wanting. In early days the loadstone was the sole source whence magnetism was supposed to be attainable, subsequently it was obtained from the influence of the earth's magnetism; but it is only within our own times that its relation with electricity has been traced, and current electricity has been made a powerful source of magnetism.

2. Unlike electricity, magnetism is not to be found everywhere and in all bodies; those it elects for its manifestations, properly so called, are very few in number, and of these iron and its near relation steel far surpass the rest; indeed, with the exception of nickel and cobalt, no other bodies were until lately known to be magnetic.

3. The native loadstone, from its irregular shape, is not convenient for illustrating the properties of magnetism; but if a steel bar be rubbed in a uniform manner with a piece of magnetic oxide, it acquires full magnetic properties, and these are developed in it in a systematic form, and are thus more open to observation. Steel so treated constitutes an *artificial magnet*, and in the form in question is called a *bar* magnet. Before we can understand the process of magnetization, it will be necessary to examine some of the properties of a magnetized bar. If suspended by a thread or placed on a point, one particular end of the magnet will always point northward; a mark is generally placed on this end, whence it is often usefully called the *marked* end; it is also called the *north* end. The other end of course points southward. This distinction between the ends of a magnet has given rise to the word *polarity*,—a term extremely useful in magnetism, but which has been most unfortunately introduced into other sciences, where it is peculiarly inappropriate. The ends of the magnet are hence often called its north and south *poles*. If two magnetic bars are brought near each other, the north

end of the one directs itself toward the south end of the other. From this we may conclude that the magnetic properties of the earth, from whatever cause they arise, are of such a character that its *north* polar regions correspond in magnetic properties to the south end of a magnet; for, like it, they attract the north end of a magnetized body.

If poles of the same name of two magnetized bars are presented to each other, they are mutually repelled; or if a freely-suspended bar-magnet be forcibly directed with its south end toward the northern regions of the horizon, it will return to its original position when the constraining force is removed.

4. Light magnetized bars, such as those used in the mariner's compass, and for other directive purposes, are often called *magnetic needles*. If the south end of a magnetized bar is presented to a compass-needle, not only will the north end of the compass-needle turn towards it, but the needle itself will be bodily attracted toward the bar; and, if not restrained, will come into contact with it, and adhere to it. No such attraction or translation in space occurs between the needle and the earth's magnetism; a needle, when magnetized, is not attracted by the earth; its gravity is not increased; it is not heavier. This is due to the infinite smallness of the largest magnetic needle, in respect to the magnetic area of the earth, as compared with the magnetic area of any bar, however large. The resultant of the lines of force, in the one case, produces merely *direction;* in the other, direction and *attraction*.

5. If a sheet of paper be laid on a magnet, and sprinkled with iron-filings, these arrange themselves about the magnet in certain curves, which have been called *magnetic curves;* and which, in some degree, represent to the eye the direction of the lines of magnetic force.

6. Not only is a magnet terminated by two different poles, but it is polarized throughout; if any doubt may be entertained respecting other instances of polarization, none can occur here; for all we have to do to discover its existence is to break a magnetized needle in half, an

we shall find a south pole to appear at the other end of the north half, and *vice versâ*, as shown in fig. 1; although, before the fracture the central point showed itself neutral.

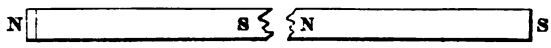


Fig. 1.

7. Inductive action is as much manifested in all magnetic as in all electrical phenomena. If a piece of soft iron is placed near a magnet, it immediately becomes itself magnetic by induction, the nearer end acquiring the opposite, and the farther end the same polarity as that of the end of the magnet to which it is presented. If not too heavy, the iron is attracted by the magnet, and moves to it; from which it appears that the attraction of mere iron and that of a magnetic needle by a magnet, are analogous, being the mutual attraction of poles of different names; but, in the one case, the pole is produced by magnetic induction, in the other case the pole existed previously.

8. If a small bar of steel is presented to a magnet it will suffer induction, as did the iron, and will be attracted. If it remains in contact a short time, and is then removed, it will be found to have acquired permanent magnetism. A small bar of iron behaves in the same manner, with this exception, that, on being removed, it parts with its temporary magnetism, and returns to its original condition. A still more close examination would show that the iron acquired its full magnetic powers instantly, whereas the steel required time for its full development. We here see the magnetic distinctions between iron and steel; iron presents little or no resistance to magnetic polarization, but it has no *tenacity* or power of retaining it; whereas steel presents very sensible resistance to the reception of magnetism, but has wonderful tenacity or power of retaining it, or as it is also termed, *coercitive* force.

9. The capacity of different kinds of steel for magnetism is various; there is a *point of saturation* for each specimen, beyond which we cannot go, and the higher this

is, and the better it is maintained, the more valuable is the magnet. In the case before us, unless the magnet were large and the steel small, saturation would not occur. In order to magnetize a hard steel needle to saturation, its whole length must be successively and repeatedly exposed to the source of magnetism. There is considerable art in magnetizing. The following plan will serve to illustrate the principle:—The needle is fixed on a flat surface; a bar-magnet is taken in each hand, one having the north, the other the south pole downward. The two bars are together brought down vertically on the centre of the needle; they are then inclined from each other, and slowly drawn apart till each reaches its end of the needle, when they are drawn off and the operation is repeated.

10. Just as we have seen a small piece of iron acquire magnetic poles by the induction of an artificial magnet, so does all iron acquire temporary, and some iron permanent magnetism, from the similar inductive action of the earth. If a *common* poker is held vertical, its lower end will show signs of north, and its upper end of south magnetic polarity, especially if it be struck sharply while in this position, or, which is better, in the true position of the dip. If the poker is now inverted, it will still be the downward end that presents north polarity, showing that it had acquired mere temporary magnetism, due to its position in regard to the earth's magnetism. We mention a *common* poker, because such articles are made of ordinary iron. A steel poker, on account of the great coercitive power of that metal, is not polarized by so small a force; however, it is not a very difficult matter to magnetise even steel bars by the mere magnetic influence of the earth. Scoresby prepared a large bar of iron, two steel bars, 30 inches by 1 inch, and six others, 8 inches by $\frac{1}{2}$ inch. He held the iron bar in the direction of the dip, and having struck it, immediately touched with it each of the large steel bars, which were also struck. He then placed the small bars in succession vertically on one of the larger bars, and struck them. He then took a pair of the small bars, and used them to rub the others, arranged with

their opposite poles connected by slips of iron: by interchanging the rubbing for the rubbed bars, he soon saturated the whole with magnetism.

11. It will have been noticed that *percussion* is of sensible service in facilitating the process of magnetization. There is every reason for believing that a modification occurs in the molecular arrangement of the ultimate particles of bodies in the act of magnetization. When a rod of iron, correctly supported, is magnetized by a process, hereafter to be described, it gives out a musical note, which, under favourable circumstances, may be rendered very audible; and this occurs at each magnetization and demagnetization, although the iron is untouched by anything. A curved iron rod will even straighten itself under magnetic influence, and a straight rod will lengthen itself. These motions and sounds indicate a derangement in the molecules of the iron; and the percussion, of which we have spoken, facilitates the change. It would seem that, under common conditions, the magnetic molecules are in a state of equilibrium, and their respective polarities neutralize each other; that the molecules of iron are easily disturbed, and then they manifest a magnetic polarity that is proper to them; that molecules of steel are less easily disturbed, on account, no doubt, of the presence of other matter than iron in steel, but when disturbed, retain their polar arrangement.

12. Electrization, as we have seen, occurs at the expense of the exciting body; what one body gains the other loses: not so with magnetization. A magnet loses nothing by imparting magnetism; it rather gains. Its action appears merely to disturb the normal arrangement of the particles of magnetic bodies; and to arrange them in a polar series. We have seen that iron-filings arrange themselves under magnetic influence, notwithstanding the interposition of paper; so it is with glass, wood, and other screens. The exercise of this force cannot be cut off by the interposition of bodies, whether indifferent to magnetism or not. In the latter case it may be modified; in the former it is exercised in its rity.

LESSON V.

DIAMAGNETISM.

1. WITHIN the last few years, Faraday has opened a new field of research; and has paved the way for other philosophers, who have also largely contributed to the knowledge of a new class of magnetic phenomena. It is now known that magnetism affects all bodies; that it attracts some, after the manner of iron, and repels others. Several of the rarer metals and also oxygen gas are attracted; other metals, at the head of which stands bismuth, are repelled. It requires a very large amount of magnetism in order to obtain evidence of these phenomena; if a horse-shoe or U-shaped magnet is employed, fig. 2, *magnetic* bodies, as iron, place themselves across from pole to pole, which position has been termed *axial*; other bodies, as bismuth, gold, water, &c., and which have been called *diamagnetic*, place themselves at right angles to the axial line, which position has been termed *equatorial*.

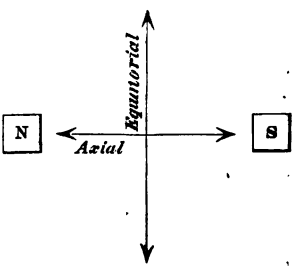


Fig. 2.

2. It is found that the denser oxygen gas is the more magnetic it proves; and, as this gas enters so largely into the composition of the air we breathe, it has been reasonably concluded that the changes of temperature, to which it is essentially exposed, are greatly concerned in producing the incessant motions of the magnetic needle; for every expansion or contraction by heat that occurs to the atmosphere is attended by a corresponding change in its magnetic capacity; and, therefore, in its reaction upon the needle.

3. Diamagnetism at the first glance appears as if it were the opposite of magnetism; and this converse character is proved to exist, by the discovery by Tyndall of diamagnetic polarity. The sphere of magnetic

force has been termed the *magnetic field;* and the general property of magnetic bodies is that they move from weaker to more powerful places in the field; and of diamagnetic, that they move from more powerful to feebler places. And hence liquids and flames arrange themselves under magnetic influence, as much in a manner peculiarly their own, as iron-filings do in a manner their own; and there are distinctions in arrangement which mark the difference between magnetic and diamagnetic liquids.

4. When a body assumes a crystalline form, it behaves under the influence of magnetism in a manner peculiar to itself; it appears as if some specimens of crystals of magnetic bodies have magnetic characters, being attracted or taking an axial direction, while others appear to have diamagnetic characters, being repelled or taking an equatorial direction; and of crystals of diamagnetic bodies, some are repelled and behave as diamagnetic bodies, while others are attracted and behave as magnetic. The mere external form determines the direction assumed by an amorphous or uncrystalline mass of matter, when presented to a magnet; but it is found to have no influence here. The phenomenon is evidently due to the molecular aggregation of the ultimate particles of the crystal, and is found to depend, not merely on the direction of the axis of the crystal, but on the direction of the planes of cleavage,—of the surfaces, that is, which are exposed when a crystal is split. The atoms of a crystal are more compressed or compacted in the direction of these planes than in other directions; and it is found that these planes in a crystal place themselves axially or equatorially, according as it is a diamagnetic or a magnetic body. So that the magnet still acts on the ultimate particles of crystalline matter, according to the usual laws, but the planes where these particles are most aggregated determine the final direction assumed by the body.

5. These phenomena have been imitated artificially by building up solid bodies of thin slices stuck together: these also have been found to assume a direction according to that of the planes of junction. The

line that represents the direction in which the contact of the particles is most intimate has been termed the *line of elective polarity;* and this line takes an axial direction in magnetic, and an equatorial in diamagnetic bodies, without any reference whatever to the shape of the body in question. For instance, a cylinder, made of paste of powdered bismuth, takes the equatorial direction proper to bismuth; but a flat cake of bismuth paste, made by pressure, takes what *seems* to be an axial direction, because the line of elective polarity, which is at right angles to the surface of the cake, requires to assume the equatorial direction. This form of force has been termed the *magneto-crystalline* force; and one important feature in it is, that it diminishes in intensity in a less ratio than the mere magnetic or the diamagnetic force, in proportion as the crystal is removed from the magnet; so that, in cases where the other forces would interfere with its results, a change of distance will neutralize their effects. Of the two ends or sides of the crystal that face the poles, it is a matter of perfect indifference which faces the north and which the south; it is not a matter of polarity, but rather, as Faraday termed it, of *axiality.*

6. When a ray of polarized light traverses rock-crystal, it suffers rotation: no such effect is produced if it traverses glass. So also if it is transmitted through oil of turpentine, or oil of lemon, it rotates in the one case to the left hand, in the other to the right: no such effect is produced by its passage through water or alcohol. But glass, water, alcohol, and other bodies, inactive as they are under common circumstances, acquire the power of rotating the ray, when under the influence of magnetism. The best substance for this purpose is a heavy glass, made by Faraday, and termed *silico-borate of lead;* and the condition, under which it is most favourably produced, is when the ray of polarized light and the *lines of magnetic force* have the same direction: these lines are represented in a general manner by the disposition of iron-filings or small magnetic needles around or between magnets. If a powerful horse-shoe magnet is erected vertically, and

ray of polarized light is allowed to pass over the poles, the source of the light and the polarizing apparatus being on one side of one of the poles, and the analyzing apparatus and the observer being on the other side of the other pole, nothing unusual occurs to the ray of light, whether the magnet be there or not: even when a piece of heavy glass is placed between the poles of the magnet and just over them, so that the ray in its course traverses the glass, nothing happens while the magnetism is cut off, but the moment the magnetism is there, the ray rotates. If it was visible previously through the analyzer, it is extinguished as soon as it is under magnetic influence; and it is necessary to turn the analyzer several degrees, in order again to make it visible: if, after being rendered visible, the magnetism is cut off, it is again extinguished, and the analyzer must be turned back in order to get sight of it again. This happens whether with white or with monochromatic light; subject to the known laws.

7. Ordinary circular polarization is limited to comparatively few bodies; *magneto-circular polarization* is exhibited in the majority of solid or liquid transparent bodies. The former is right-handed or left-handed according to the nature of the body, in whatever direction we observe the ray; the latter is absolute in direction, and if right-handed, observed in one position, it is left-handed if observed in the reverse position. If the arrangement of the apparatus is such that the north pole is the nearer to the observer, as in the following plan—

Light,—*polariser*,—S. POLE,—*glass*,—N. POLE,—*analyzer*,—observer—

the rotation is from left to right, like the hands of a watch; if the observer and the light or source of the ray change places, (the rest of the apparatus remaining untouched,) as under,

Observer,—*polariser*,—S. POLE,—*glass*,—N. POLE,—*analyzer*,—light—

the rotation is to the observer from right to left. This is not the case in common circular polarization; for in the following arrangement, when, in place of glass, naphtha is substituted, a body capable of producing the effect without the help of magnetism,

Light,—*polariser*,—NAPHTHA,—*analyzer*,—observer—

the rotation is to the observer left-handed, whether the arrangement given above is adopted, or the observer and the light change places.

8. The angle of magneto-rotation, like that of natural rotation, is different for different bodies: water, heavy glass, oil of turpentine, are in the relation of 1, 6, 11·8; and it is greater in proportion to the length of the ray under magnetic influence, all other things remaining the same. It is also altogether independent of the natural rotative power; for if the following arrangement is made,

Light,—*polarizer*,—S. POLE,—*naphtha*,—N. POLE,—*analyzer*,—observer—

the ray will rotate to the left by ordinary and to the right by magneto-polarization, and the *difference* of the rotations will be observed: if the observer and the light change places, the rotation will be left-handed from both causes; and the *sum* of the rotations will be read off. All these effects require much magnetism: they can be produced, but more feebly, by the aid of one pole, and, theoretically, in all directions, except when the ray passes at right angles to the lines of magnetic force. A remarkable condition in these phenomena is, that no effect is produced on the solid transparent body or on the ray, if either is operated upon *alone*; but only when the ray is *traversing* such a body.

9. That these relations extend to common light, may reasonably be concluded; although we have not the means of detecting them. They have also been proved to extend to polarized rays of heat, which are equally found to rotate, under the influence of magnetism.

LESSON VI.

ELECTRO-MAGNETISM—MAGNETO-ELECTRICITY.

1. WE pass on to consider the relations between magnetism and electricity,—*Electro-magnetism*, as it is called; for we are better prepared to enter upon this subject, now we have glanced at the leading features of magnetism itself. An electric current and a magnetized needle have a tendency to assume positions at right angles to each other: if the conducting wire is fixed, and the needle is light and free to move, it will move; if

the magnet is heavy and the wire light and mobile, the current with its wire moves. The direction it will take is easily remembered. If the observer conceives a current to be descending from his head to his feet, and is looking at the N. end of the needle, the N. end will be deflected to his right hand; and this is true of any N. pole, whether of a horizontal, or of a dipping, needle, and whether on the near or far side.

2. Two currents produce a greater effect than one; many, a greater effect than two. Hence, if we suspend the needle in a coil of insulated wire, and send the current through it, the effect is multiplied, and we have the instrument called the *multiplier* or *galvanometer*. If the needle of the galvanometer is vertical, as in electric telegraph instruments, the currents that descend the front of the coil ascend the back, and the effects are combined to produce a deflection. For large quantities of current force a few yards of thick wire are used, a few multiplications being sufficient to give a result; but for small quantities, several thousand yards of fine wire are used, in order, by many times multiplying the feeble force, to obtain sensible indications. An ordinary galvanometer merely indicates that one force is greater than another, but does not indicate *how much* greater; but there are galvanometers depending on certain mathematical laws, by which true relations are obtained.

3. When a compass-needle is fully deflected, nothing more can happen; the N. pole has gone as far as it can to the right, and the S. pole as far as it can to the left, and it now rests in a state of equilibrium. But, by contriving that only one pole shall be under the influence of the current, continuous motion can be produced.

4. Suppose a jar of mercury (fig. 3) to be on the table, and a wire, D, to descend from the ceiling to the centre of the mercury touching its surface, and a current to be descending the wire and to be dispersed on reaching mercury: suppose further that a wire index D N rests e mercury, having free motion round the wire as re, and that it carries at the end a ball, N, and

that this ball represents a N. pole. It is clear from what we have before said, that this N. pole will move to the right, as shown by the arrow in the figure; and not only so, but will continue moving to the right, and therefore will make a circuit of the current as long as current of sufficient force is there. In practice, it is not possible to have a north pole without a south; but in the apparatus for producing this rotation, a bar-magnet is placed in the jar with the S. pole downwards, and tied by a thread to the bottom in the centre of the jar, and the N. pole is adjusted to be just at the surface. The current, which is concentrated in the wire, is free to act by the known laws on the N. pole; but it is diffused in the mercury, and the S. pole being in the midst of it, has no tendency, even if it were free, to move either way. The current passes on by a wire at the bottom of the jar. If the direction of the current, or the upper pole is changed, the rotation is left-handed; if both are changed, it is right-handed.

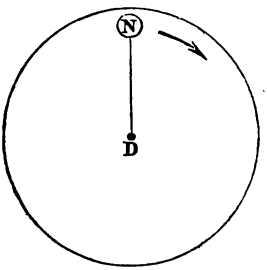


Fig. 3.

5. Setting out from this principle, apparatus has been constructed for exhibiting the rotation of poles and currents, either about the other, and also of magnets on their own axes. In the latter case, the magnet is pivoted vertically and stands half-immersed in mercury, the upper half being employed as the conductor of the current: the pole of this half and the current of this half are alone concerned in producing the effect, the current being diverted from acting on the lower pole. The operation of the law is easily recognized in this experiment; for if we consider the whole section of the magnet endowed with N. polarity, and the whole section traversed by a descending current, and take any spot of current, and look in all directions at the magnetism, we in every case find the necessity for a right-hand movement; and, as the current is continuous, a rotation.

Currents are equally deflected by the magnetism of the earth.

6. Currents have a mutual action upon each other. The general law is, that currents moving in the *same* direction *attract* each other; those moving in opposite directions *repel*. The effects are necessarily feeble, and require more delicate apparatus than that used for showing the relation between magnets and currents.

Now, since the same current has power to move either a magnet or another current, it shows that there must be some analogy between magnets and currents.

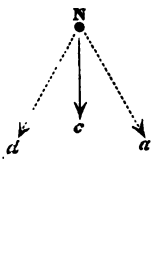


Fig. 4.

If, in fig. 4, N represents a north pole, D a descending and A an ascending current, the former will tend to move the north pole to the right or towards A, in the direction of the dotted arrow *a*, the latter, to move it to the left, or towards D, or in the direction of the other dotted arrow *d*, the two forces combined tend to move it in the direction of the central arrow *c*, or, in other words, the magnet will attract the current, or the current the magnet; the reverse or repulsion would have occurred with the south pole. If we now conceive ourselves placed at N, and looking toward the currents, we shall see that the one facing our own left hand is ascending and the other descending; and if the upper ends of the wires and the lower ends were joined so as to form a circle, we will have a current moving in the same direction as the hands of a watch: we see, therefore, that such a circular current would be attracted by a north pole; consequently, it has the same properties as a south pole. And this is true in practice as well as theory; for if little bits of zinc and of copper be floated by cork separately in acid water, and connected by a long piece of thin cotton-covered wire, wound in a ring of many convolutions and standing vertical, the

side where the currents, as we look at it, are moving in the direction of the hands of a watch, will turn round and face the south, and the other side, in which they are in the reverse direction, will face the north. If the wire is wound into a long spiral, instead of a flat ring, the same law holds good; the end, where the currents are dextro-gyrate, comports itself like the south pole of a compass-needle; the end, where they are levi-gyrate, like a north pole.

7. Not only does an electric current so arranged resemble a magnet, but it is also able to produce actual magnetism in iron and steel. When wire is coiled round on iron bars or horse-shoes, and a current passes, the iron is powerfully magnetized, and constitutes that useful instrument in physical research, the *electro-magnet*. The power of such magnets is unlimited; for, by increasing the iron, the conducting wire, and the voltaic battery, and adjusting each properly to the others, we obtain magnets of almost any lifting power. When the current is arrested, the magnetism of the iron ceases. The experiments on polarization, that we have been describing (p. 298), are made with a powerful magnet of this kind, and the application or removal of the magnetic influence, of which we then spoke, is accomplished by turning on or cutting off the voltaic current. The purer the iron is the more perfect is its action, and the more truly does it part with its magnetism; bad iron retains a little permanent magnetism. Steel is very readily and perfectly magnetized by these means. It is when iron is magnetized by voltaic currents that it gives out the musical notes of which we have spoken (p. 294).

8. Upon the facts before us, that a circular current comports itself in all respects like a magnet, and that it converts iron or steel into a magnet, Ampère founded his theory, that a magnet may be considered as made up of currents all circulating in the same direction around its surface, and these external currents as the sum or resultant of molecular currents circulating around each atom. Why these phenomena should be manifested in so exalted a manner in iron, in so moderate a manner

in nickel, cobalt, &c., and so different an action be found in diamagnetic bodies, remains to be discovered. De la Rive has noticed that magnetic bodies contain the greatest number, and diamagnetic bodies the smallest number, of chemical atoms in the same volume: and he considers that the electro-atomic current, on this account, is less easily established in the latter than the former.

9. We must not be led to suppose that a continuous current is necessary to produce the amount of molecular disturbance in iron which constitutes magnetism. The instantaniety of a flash of lightning constantly demagnetizes the needles of the electric telegraph, and often remagnetizes them in the reverse direction; the two operations being performed in this minute interval of time. Advantage is taken of this property for constructing instruments that shall turn on and cut off electric currents, by making and breaking contact with extreme rapidity. A small piece of pure and soft iron is adjusted in front of an electro-magnet: when the current circulates it is attracted; but, the moment it moves, it alters a connection and cuts off the current; and then, as there is no magnetism, it falls back, which again makes connection and turns on the current, and so on. Instruments of this kind will make numberless contacts in a second. When the original current is employed to produce an induced current in a second wire, intense effects are obtained; for *one* induced current is produced for *each* prime current; and if a considerable number of these occur in a second, the secondary effects are highly exalted.

In steel bars and in large pieces of iron, a sensible time is required—a second or more—in order to produce the full effect; in the one case there is the coercitive force to overcome, and in the other, the large mass of particles to be disturbed from their normal state and rearranged.

10. In order to produce an induced current in a secondary wire, all we did was to wind the primary wire first on a bobbin, and then wind the secondary wire outside; the wires being insulated along their

whole length by cotton or silk. When a current commenced in the primary, a reverse current occurred in the secondary; when it closed, a similar current occurred, and both were instantaneous. The primary current is the actuating cause, the wire merely a vehicle for introducing it; and hence if we wind the secondary wire on a hollow bobbin, and the primary wire on a bobbin small enough to enter the other, and cause a constant current to circulate in the latter, we readily produce induced currents as we thrust it in or draw it out of the other.

11. But we have seen how truly a magnet resembles a current; and hence we are not surprised to find that induced currents are obtained on thrusting a magnet instead of a coil into or on drawing it out from the larger coil; and in the same way, by moving a magnet near a conducting body, or a conducting body near a magnet, we obtain electric currents. This branch of the science is termed *magneto-electricity*. As the earth possesses considerable magnetic reaction, it follows that no conducting body can move without the development in it of current electricity; and, by suitable arrangements, this electricity can be collected and examined. In order to increase the intensity of secondary induced currents, advantage is taken of this inducing power of magnets, and the primary wire is wound round an iron core, which becomes magnetic, and conspires with the original current in producing the result.

12. In order to obtain from magnets continuous induced currents, Faraday rotated a copper disc between the poles of a horse-shoe magnet; the poles being near the edge of the disc. He collected the current by wires, one placed at the centre and the other at the circumference, near the magnet. The relation of the current produced to the poles and directions is such that, when the S. pole is under the edge of the plate, and the latter revolves over it in the direction of the hands of a watch, the electricity collected at the *edge* of the plate nearest the pole is positive; that collected at or near the centre is negative; or the direction of the current is

such, that the positive current moves from the circumference to the centre. When the collecting wires are away, the discharge takes place through the neighbouring part of the disc; when they are there, it occurs through them and the instrument to which they lead. This is precisely in accordance with the law that a primary, or an existing current, induces a secondary current in an opposite direction in a conductor near it, at the time it is called into existence, or brought near it while it is in existence. Remembering that Ampère's currents circulate round a south pole in the direction of the hands of a watch, as at S in fig. 5, if we conceive the line P N as one radius of the disc (and what holds good of one radius holds good of all the disc), and that it is moving onward to the right, over the S. pole, a current will be induced in it in a direction the *reverse* of that indicated by the nearer arrow, *a*, and therefore in the direction from P to N; and it may be collected at P and led to N through the wires of a galvanometer; and when this is not the case, it will get to N by discharging itself through the substance of the plate. If P′N is another radius, after it has passed the pole, and on its journey away, we shall still get positive electricity at the circumference; for, on leaving the magnet, it has an induced current in the *same* direction as that indicated by the primary current, *b*, nearest to it; and this gives a resultant from P′ to N, or positive at P′ and negative at N, as before. If the disc rotates between two different poles, their action is combined, and a more exalted result is obtained. By this arrangement, and a continuous rotation, an uninterrupted current was first obtained. This is the simple form of a *magneto-electric machine;* but when a U-shaped iron armature is rapidly revolved before the poles of a powerful horse-shoe magnet, each end be-

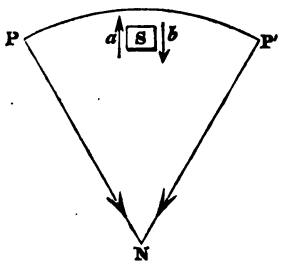


Fig. 5.

comes continually first a north and then a south pole; and if these ends constitute the cores of long bobbins of insulated copper wire, a rapid succession of currents of electricity is produced in the bobbins, and, by suitable arrangements, the currents can be collected and turned to useful account. They produce all the known effects of electricity derived from any of the other sources.

CHARLES V. WALKER.

Telegraphs.

BY CHARLES V. WALKER.

LESSON I.

EARLY EFFORTS.

"Canst thou send lightnings, that they may go, and say unto thee, Here we are?"

1. THE word Telegraph is composed of two Greek words, signifying to write or describe at a distance; and to do so in some way is a part of our every-day existence. The organs of speech enable a man to convey his ideas to a moderate distance; the organs of hearing enable another to receive the ideas. When he has other sounds to contend against, and would convey his ideas in a given direction, he employs the speaking-trumpet, and his object is attained. When he would communicate by word of mouth to greater distances, and many physical obstacles are between him and the object of his desire, he employs a tube, and is able through all the deviations and irregularities of its course to make his words be heard. In most common cases, when he would merely notify his presence and convey but few ideas, he strikes a blow.

2. The blows are sometimes struck at a distance, and bells are rung by aid of wires or ropes. Sometimes they tell their tale merely to our own household; sometimes the village bells resound throughout the vale, and all who hear know but too well whether they call to prayer, or gladden the heart of the trembling bride, or say that one more soul has passed into eternity, or sadly call the mourners on their way to

commit to its kindred dust all that remains of one they held most dear. Sometimes the sounding metal tells of the hidden rock, or calls a slumbering town to be up and doing, for danger is at hand. The trumpet's note is no uncertain sound; it tells the soldier when to charge the foe, and when he must retreat; it rouses him from his slumber, or, with another note, it calls him home to rest. The signal-gun proclaims a ship distressed; the minute-gun that some one great or noble is carried to the tomb; the *feu de joie*, that 'tis some gala day; the magic twenty-one that England's queen is near, or that some day has come, eventful in the history of our time.

3. These are all but different illustrations of the means we have adopted to convey our wishes afar. The great advantage of sound is that, especially to a man awake, it *commands* attention, the ear is never closed; and, if loud, it will even awake the sleeper. But it does not penetrate far into space, and its language is limited. Light travels with extreme rapidity, and penetrates to very great distances; for instance, the sun is nearly a hundred millions of miles from us, and yet what a volume of sunlight surrounds us! The distance of the stars is reckoned in millions of millions of miles, and yet the rays of light come to us with great distinctness. The whole coast of this sea-girt England, for instance, sends forth its messengers of light amid the gloom of night to tell the mariner his whereabout; on this point a single steady light proclaims its name afar for many a mile; on this, a light is one time bright and then for a time is hid, and so it speaks; here we have two fixed lights, and here one fixed and one that is often hid. The sound of the seaman's signal-gun will not at all times reach the shore; he then throws up a light, a rocket mounts on high, and tells of his distress. The rays of green or red or white light are the only things well visible to the engine-driver in a pitchy dark night, and yet he drives in safety along a road to him invisible; they tell him, in language unmistakable and easy to him, before he comes upon them, whether he shall stop, or come with care, or boldly drive along. He tells also to others of his coming, by a bright white light, or two or

three, according to his mission; and he warns all followers to keep their distance, by a deep-red light, that speaks as plain as language, that he is on before. By day, when all is light, the distant semaphore, with its arm full up or half way down, or altogether lowered, advises him betimes to stay his course, or slack his speed, or come securely on; a full red disc forbids him to go on, or else it turns its edge to say the road is clear.

4. A few years since, until electricity had proved its goodness, a tall mast was seen on the Admiralty, at Whitehall, furnished with two or three arms, the motions of which were often an object of interest to the passer-by; they were seen to move into different relative positions, and for a second or two remain so, and then be changed again in position. These positions corresponded with numbers; and, by reference to an extensive code-book, were convertible into language. When a signal was made it was held up till recognised and repeated by a similar instrument on elevated ground a few miles distant, from which it was repeated by another station, and so on till it reached the coast.

5. This sort of visual telegraph was carried out to a great extent in France by the brothers Chappe. Their semaphore was mounted in like manner on a tall pole, and consisted of a long arm, at either end of which was a short arm. The long arm could be set in a vertical or horizontal position, or inclined 45° from the horizontal on either side; each short arm could also be set in one of eight positions in respect to the long arm. Fig. 1 shows the

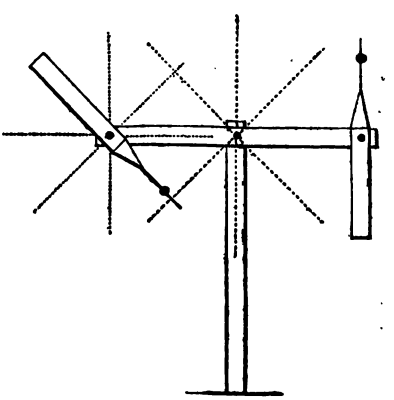


Fig. 1.

long arm in the horizontal position, the right arm in the downward vertical, and the left at the left angle of 45° from the vertical upward; the dotted lines show the other three positions of the large arm, and the other seven positions of the left-hand small arm, the same, of course, applying to the righ-thand small arm. The extension with the weight attached is the counterpoise to the small arm. —With the long arm inclined to the right ninety-two positions or signals could be made—these referred to the ninety-two pages of a vocabulary; each page contained ninety-two words; and, having in this way first made one signal to indicate the page, a second signal followed to indicate the word; by this simple combination of two signals any one of 8,464 words could be expressed. The MM. Chappe constructed a phrase-book, and a geographical-book of the same extent; and all that was needed was at the commencement of a correspondence to give a previous signal to indicate what book was to be used. The ninety-two signals shown by the arm when inclined to the left indicated certain matters connected with the message or the service; as, urgent, great haste, haste, the destination, the conclusion, leaves of absence, error, delay, fog, rain, accident, wind, fire, &c.

6. These signals ceased to be available when night came on. Dr. Guyot, in 1840, published a plan for attaching lanterns to the arms of the Chappe semaphore; and for so arranging the code that one book should contain all the signals, to have 288 pages, each containing 288 words, phrases, letters, or signals, in all 82,944; but it does not appear that his plans were adopted. The system of signalling by flags is very much of the same nature; a ship makes itself known by hoisting certain flags, to indicate its number, against which, in the signal-book, its name will be found; other flags indicate the class of signals that are to follow, and, by reference to that division of the signal-book, the message given by other flags is read. Sir C. Napier expressed with a few pieces of coloured bunting the words "Well done, Arrogant and Hecla." Night and especially fog are fatal to correspondence by these means.

7. Although sound and light and locomotion have now

all yielded the palm to electricity, it is curious to review Dr. Guyot's ideas, of only a few years ago,—and he was only one of thousands,—who foresaw the difficulty of erecting and insulating wires, of protecting them from malevolence; of keeping up supplies of electric force; of sending the force to a distance; the expense of training and maintaining an enormous staff; of stores, too, and apparatus, and the "thousand other practical difficulties which unite to terrify the boldest imagination." But these apparent difficulties have vanished before the persevering ingenuity of man, and have settled themselves down into the mere routine of every-day duty.

8. As soon as electricity had revealed the great velocity with which it moves, and this was towards the latter part of the last century, the idea had birth of causing it to produce distant signals; and many curious suggestions were made: but seeing that, in those days, friction was the only practical source of electricity, and tension the only form in which it was developed, it may readily be supposed that no great progress was made towards a true and useful telegraph. The difficulty of generating free electricity at command, and the extreme precautions required for its insulation, were serious obstacles in the way to success; so that we can scarcely regard the telegraphs that were then constructed or proposed, in any other light than as philosophical apparatus to illustrate the idea of electric-telegraphy.

9. Sparks and repulsions were the two forms under which it was first proposed to employ free electricity. One or more sparks, variously combined, were to constitute the signals; or the letters were to be traced in tinfoil, which was so cut away in the course of the discharge, that the group of sparks occurring at the intervals showed an illuminated letter. Attention was in some cases to be gained by the spark occurring in hydrogen gas and air, and so causing explosion. As late as the year 1844, Highton proposed piercing papers with sparks; and he reports that he tried the plan with success, by means of a small Leyden jar, along a distance of ten miles; but it has never been turned to practical account.

10. One philosopher proposed a couple of dozen pairs

of pith-balls or gold leaves, and as many wires, a pair for each letter, and whichever wire was electrized, its leaves diverged. Some proposed fewer pairs, and conventional signals. In 1816 Mr. Ronolds insulated eight miles of wire, on his lawn at Hammersmith, with silk and dry wood. He had a clock at each end, and each clock carried a disc with letters on the circumference; a screen was in front of this disc, and, through a hole in the screen, letter by letter was seen as the disc revolved; and as the clocks were uniform in motion, the same letter appeared at the same time at each station. A gas pistol was fired to call attention. Then, as soon as the letter came in sight that was wanted, the sender electrized the wire, and a pair of pith-balls at the distance diverged; when the next required letter came, he did the same, and so on till his message was spelled out. The receiver made a note of the letters that were visible whenever he saw the balls diverge. The same experiment was tried through 525 feet of wire buried in glass tubes in a trough of pitch.

11. These and other experiments firmly established the idea of applying electricity for telegraphic purposes; and the discovery of current electricity, at the opening of the nineteenth century, was soon followed by attempts to carry out more successfully the well-recognised idea. Many of the early attempts ended in producing various ingenious philosophical toys, but no apparatus worthy of being dignified by the name of a telegraph. About ten years after the discovery of the voltaic pile, Soemmering proposed thirty-five wires, terminating in gold points in acid water, each to represent a letter, sign, or figure; the water was decomposed, and gas given off at the two points, through which a current of electricity was sent; and thus two letters were indicated, the point at which hydrogen was given off indicating the first letter. He called attention, by holding on the current till enough gas collected in a receiver to produce motion and liberate a ball and let it fall on a bell. About the same time other cases of decomposition were proposed, so as to produce change in colour. Nearly thirty years later, it was proposed to reduce the thirty-five wires to two, and by strong

or weak currents, and long or short intervals, to form an alphabet. About the same time it was elsewhere suggested to put the ten fingers upon ten wires, each finger to represent a signal, and to discharge electricity by one or other wire, and thus give a shock to one or other of the fingers, according to the signal required. Dr. O'Shaughnessy suggested administering shocks, according as the required signal was brought to view by discs revolving by aid of sympathetic clocks.

LESSON II.

ELECTRO-MAGNETIC TELEGRAPHS.

1. In 1819 Œrsted laid the foundation of electro-magnetism, having discovered the relation between current electricity and a magnetized needle. And in the following year it occurred to Ampère that a set of galvanometers might be prepared, each with its own wire and one for each letter, and that their deflections at a distance, by means of current electricity, would constitute a practical electric telegraph. There was evidently something manageable in the galvanometer; and Ampère's ideas were re-echoed and expanded. In succeeding years we find propositions of one coil and two needles; thirty wires and needles to carry screens; thirty-six wires and needles; twelve needles and screens; one needle; two dozen needles; five needles; then we have crescent needles, horse-shoe needles, and suspended needles.

2. The electro-magnet has also been very extensively introduced into the construction of telegraphic apparatus, either for moving an index, or for liberating clockwork, or for making marks or punctures, and in many other ways. It would, indeed, require volumes adequately to describe the various applications of the fundamental principles of electricity to the construction, not merely of impracticable apparatus, but of real working electric telegraphs. It will serve our present purpose to select from the telegraphs now in use, and that have gained a reputation, some striking illustrations of the manner in which the principles are carried out.

3. Cooke and Wheatstone's double-needle instrument

is familiar to every one who has seen a telegraph station in England. It has been from the first established in this country, and has well maintained its ground: the instrument of to-day differs but little from its predecessors, and the difference is only in detail; the galvanometers are made more delicate, the needles more sensitive; the mechanical parts firmer, and the whole more compact. It consists of two vertical galvanometers, to each of which a separate wire is devoted. An axis carries two needles, one within the coil of the galvanometer, and out of sight, and which, from its position, is most concerned in producing the action, and the other in front of the coil, outside a dial, serving as the index; the inner needle has its north pole downward, the outer, its south. A current passing in one direction through the coil deflects the index-needle to the right; in the other direction, to the left. The letters of the alphabet are made by one, two, or three, and in some cases four movements, of one or other or both needles. The letters begin with the left needle; and when its combinations are exhausted, proceed to the right needle, and finish with both needles. For instance, A and F, I and O, S and X, are made by two motions; B and G, K and O, T and Y, by three motions. The first pairs are made with the left needle, the second pairs with the right, and the third pairs with both. The first of each pair is made by left-hand deflections; the second of each by right-hand. When two needles are used, the deflection of the bottom half of the needles is read off.

These signals and all others are made and read with extreme rapidity by the initiated, but naturally puzzle a stranger. Wires are led from instrument to instrument in the same group, in such a manner as to cause the signals on each to correspond.

4. The current employed for actuating these instruments is obtained from the simplest form of voltaic battery. A trough of wood, gutta-percha, or glass is divided into cells; the cells are furnished with amalgamated zinc and copper plates, and then filled with sand, saturated with sulphuric acid and water; or, which is better, with plates of amalgamated zinc and graphite, no

sand being used, and the zinc being retained by contact with mercury in a permanent state of amalgamation. The number of cells employed depends on the distance along which the signals must travel. We have thus, in the galvanometer and the battery, the essence of the telegraph; and the only portions at all complex are the mechanical arrangements for bringing these two things together—for guiding, that is, the voltaic current at will in this or that direction through either or both coils.

5. This operation may be very well traced in fig. 2.

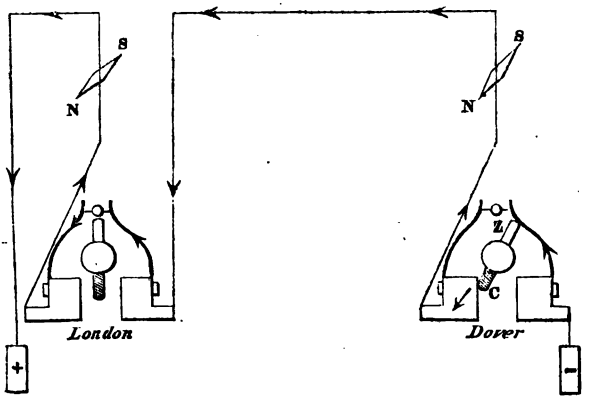


Fig. 2.

It represents a telegraph needle at London and another at Dover; it shows how the wires are arranged for establishing communication between the two; and it further shows the mechanical operation by which a signal, made at Dover, is shown both there and at London. It shows, indeed, the actual section of an instrument, except that, instead of a coil of wire round the needle, which would make the matter less simple, we have merely introduced a single wire between the spectator and the needle; for what is true of one wire is true of every wire of the coil. The needle here represented is the one that is within the coil, and invisible to the eye in the actual instrument. The mechanical parts of the instrument consist of two vertical curved springs, whic'

rest on metal points, and are thus in connexion, and either of which can be lifted off, as shown in the right-hand spring of Dover; and of a brass cylinder, into which two metal studs are fixed, insulated from each other by boxwood. The upper stud, Z, is connected with the zinc end of the battery; the lower one, C, with the copper end. This cylinder is shown in a state of rest in the London instrument, and deflected to the right in the Dover one.

6. By following the arrows, the course of the current from Dover to London is manifest. After passing the instrument at London, it is led into the earth by a wire attached to a plate of metal or to the water or gas pipes. The instrument at Dover is also connected by a wire with the earth. We have marked the earth plates respectively + and −, to indicate the states of electric tension they present: these states are immediately neutralized by the electricity of the earth, and the discharge of each end of the battery occurs, without any need of an actual current passing in the earth between them. It will be seen that the instruments are so connected, that if an ascending current occurs in one, it shall also occur in the other; and that if the handle and cylinder of one instrument are deflected to the right, the needle of each instrument shall be deflected in a similar direction. In the case before us, the ascending current in front of the needle deflects the south end to the right, according to the laws already laid down. The copper stud C is arrested by a strong brass block, which serves the double purpose of a connection between it and the coil, and of a stop to limit the motion of the handle and cylinders.

7. The London galvanometer is thus in the circuit of any current that may pass along the wire from end to end, and in a condition to *receive* signals. The Dover instrument is in the condition of *sending* signals; and a little study of the figure will show that the act of sending a signal consists in *cutting* or *breaking* the circuit, and *inserting* the two battery *poles* in the breach thus ›rmed; and the handle, the cylinder, the studs, the ings, and the stops, are mere mechanical arrange-

ments for accomplishing this much more rapidly and successfully than could be managed by the simple acts of cutting, inserting, and mending. The various wires, and slips of metal, and binding-screws, which are apparent in instruments, and which give them a complex appearance, are nothing more than the metal connections by which the line-wires, the earth-wires, and the battery-wires are each connected with the proper parts of the coil or the mechanism. If half-a-dozen or more stations occur between the two terminal stations, and instruments are properly inserted in the wire, the same motions will occur in each, and the same signalling power will be possessed by each. If the handle is deflected to the left, the reverse deflection occurs.

8. At stations where it is necessary to call attention by a bell, the telegraph-wire is cut, and the ends are led to the ends of the coils of an electro-magnet, in the front of which a keeper of soft iron is balanced; this keeper acts as a stop to a clock-train, always kept wound up. When a current is sent along the line, the keeper is attracted, and the train liberated, which moves a hammer and strikes a bell. Sometimes the bell has a wire to itself; at other times it is on the galvanometer or needle-wire; and then, when talking is going on, the current is made to avoid the electro-magnet, by having a path prepared, opposing less resistance. There is an alphabet provided for a single galvanometer which is necessarily more tedious, but is very useful in the event of one wire failing, and also for stations where very little speaking power is required.

9. Morse's telegraph is very extensively used in America. It is an illustration of the application of the electro-magnet. The keeper of the magnet is at one end of a lever, and a blunt point at the other; and when a current passes and magnetizes the iron, the attractive power is sufficient to cause the point to make an indent on paper. The paper consists of a long slip or ribbon, and is on a drum which revolves when a message begins, and draws the ribbon of paper in front of the point; the point makes dots or marks, according as the keeper is held on by an instantaneous or a continuous current

The alphabet or numerals are composed of combinations of from one to five dots and dashes. A dot and a dash make *a*; a dash and three dots *b*; three dots *c*; a dash and two dots *d*, and so on, according to a prepared plan. The signals are sent by simply pressing down a stud, which puts one pole of the battery on the wire in a given direction, the other pole being fixed in the other direction. The resistance of long lengths of wire is not favourable to making powerful electro-magnets at a distance; therefore, in Morse's telegraph, the current that is sent merely actuates the electro-magnet of a pecker or contact-maker at the distant station, and this pecker completes the circuit of a local battery with the larger electro-magnet of the telegraph itself, and thus forcible attractions are obtained and marks made. Grove's battery is used, the number of cells being accommodated to the distance.—By using bobbins of about six inches in length and stout copper wire covered with cotton, electro-magnets of a more powerful character may be made to act at a distance. Signal-bells are constructed in this way: the keeper of the electro-magnet carries a hammer, and is so strongly attracted when the current passes, that the hammer flies forward violently, and strikes a loud blow on a large bell. Trains are, under certain circumstances, signalled by such bells; one blow designates one kind of train, two or three blows, other kinds. Eight or ten cells of Smee's battery, which is platinized silver, amalgamated zinc, and acid water, give sufficient power at a mile distance to strike loud blows on the large bell, and by extension of the coil and wire on the battery, the distance is easily extended.

10. Henley's magneto-electric telegraph, now used to some extent in England and Ireland, is a double-needle telegraph, but the needles move by means of an electro-magnet, not a galvanometer coil. The needle is magnetized, and an iron crescent is fixed upon each pole of the electro-magnet so as to extend it into two ends, and the needle is thus placed, when a current is passing, with its N. end between a north and south pole, and its S. end between a south and north pole, somewhat in this fashion (|), and the four poles thus conspire to

produce the deflection. The electric force employed for Henley's instrument is obtained by moving coils of wire in front of magnets, and is sent in one direction only, so that the needles have each a single deflection. Magneto-electricity has been for a long time profitably employed for sounding alarums: its great advantage is its constancy; its force does not vary, so that when the bell mechanism is once adjusted to the force at command, there is no fear of failure from reduction of force, or of derangement from excess of force.

11. When the French government had resolved to adopt an electric telegraph, one of the conditions was that the instrument should in some degree be a reproduction of the Chappe semaphore already described; so that the same form of manipulation and the then existing signals and codes should be available; and that the same staff of employés could be ready for the service without much further training. This condition was not literally complied with, for the long arm of the Chappe semaphore was made a fixture in a horizontal position in the electric telegraph, and the short arms alone, at either end, were susceptible of motion. Each of these arms was on the axis of a scape-wheel with four teeth in which a pair of pallets worked. The pallets were connected by certain adjustments with the keepers of a small electro-magnet, and were so arranged that the complete escape of one tooth, or a quarter revolution occurred when the keeper was attracted and then liberated, and the eighth of a revolution occurred when the keeper was attracted only and not liberated; so that by successively sending and cutting off the current four times, the arm would take the eight successive positions, and would perform a complete revolution. A pair of handles, one for each arm or index, are mounted in front of the instrument, and are so connected that one rotation of the handle turns on and cuts off the current four times, and so produces the eight signals and complete revolution of the index; and the respective positions of the handle correspond with similar positions of the index. Each of these positions has a technical name, with which we need not now concern ourselves. The various positions

combined give an alphabet, and a series of conventional and code signals. The left index vertical downward is *b*, vertical upward is *f*; the right index vertical downward is *n*, vertical upward is *i*; both indices horizontal is the beginning of a despatch; the right horizontal and the left vertical downwards, the end; and so on. These several positions may be readily understood by referring back to the sketch of the Chappe semaphore (fig. 1). The telegraph instrument presents a face of about a foot square, and shows the horizontal arm fixed, at either extremity of which are little models of the small arm with their counterpoises. When the instrument is in action, the latter move round, not in the sober sluggish style of the old semaphore, but with great liveliness and rapidity, and also with great truthfulness.

12. Bain's chemical printing telegraph is used in England to a considerable extent by the Electric Telegraph Company. In practice, it consists essentially of a long ribbon of paper, wound on a drum; the paper is moist with a chemical solution, that suffers decomposition and changes colour, when an electric current passes it. When a message is in progress, a clock-train is liberated, and the paper allowed to run off, between a metal roller and a point. These two things are so placed in the circuit, that when a current is sent from a distant station, electric force passes between the point and the roller; and as the moist paper intervenes, the current of course passes through the paper; and, in consequence of the property already mentioned, it decomposes the solution contained in the paper, as long as it is allowed to pass; and as the paper moves on, either a dot or a mark is produced, according as the current is made to be instantaneous, or is allowed to have a certain limited duration. These dots and marks constitute the alphabet, somewhat after the same fashion as Morse's, but differently combined. One dot is *e*; two, *o*; three, *c*; one dash, *i*; two, *y*; three, *z*; a dot and a dash, *a*; a dash and a dot, *u*; two dots and two dashes, *n*; two dashes and two dots, *w*; and so on. The signals are sent by means of a pecker or contact-maker, which is rapidly touched for an instant, or for a sensible time, according as a dot or a mark is required.

LESSON III.

SIMULTANEOUS MESSAGES AND TIME-SIGNALS.

1. THERE is a process by which two stations, London and Dover for instance, may each send a message to the other at the same time and by aid of the same wire, without either interrupting the other; while London, perchance, might be informing Dover of some great conflagration in the City, Dover might be advising London of a calamitous shipwreck in the Channel; and each piece of intelligence could be read off simultaneously, although but one and the same wire existed. And what at first sight seems almost paradoxical is, that this twofold operation is accomplished, not because two currents *can* travel at the same time in opposite directions, but because they *cannot*.

2. If two equal voltaic batteries are so connected as to be opposed to each other; or, which amounts to the same thing, if two equal and opposite currents are presented to each other on the same wire, the effect is null; if they are unequal, their difference, subject to certain corrections, is alone manifested. The arrangement for accomplishing the twofold operation in question is founded upon the fact, that two equal and contrary currents neutralize each other or produce a null effect. Let A and B (fig. 3) represent the telegraphs at the two distant

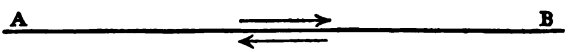


Fig. 3.

stations in question connected by the wire A B. Under the common arrangement of telegraph instruments, if A sends a current to B in the direction of the upper arrow, or if B sends one to A in the direction of the lower arrow, or *vice versâ*, either of the four effects is visible at both stations. But if, while A is presenting a current to the wire in the direction of the upper arrow, B is presenting an equal current in the direction of the lower arrow, the effect is null at both stations. If now the instrument at A (fig. 4) is so arranged that the clerk at A can send two distinct and equal currents through his own

instrument, one of which goes along the wire to B, and the other does not, it is obvious that the effect is null in

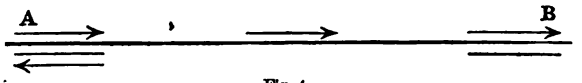


Fig. 4.

the instrument at A and is active at B; so that by this process, although A is talking to B, he does not see his own message on his own instrument. The same, *vice versâ*, would be the case with B if he had an instrument so constructed; and this mode of construction, for sending without seeing, would not interfere with the power of receiving, as shown by the additional wire at B, not now in use. But if, while A is sending a message, as shown by the figure above, B desires at the same time to use his instrument and send one also, he will send two equal and reverse currents through his own instrument, one going to A, which I have designated in fig. 5 by the highest row of arrows, the other going

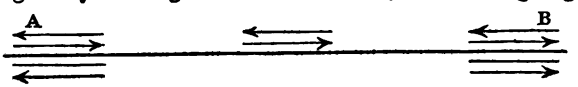


Fig. 5.

only through his own instrument, designated by the lowest of the three arrows. Now, as the condition is that all these currents are to be equal, the instruments at A and B will be seen to be active, and the effect in the wire itself to be null; for in each instrument two currents are seen in one direction opposed to one current in the reverse direction, and the difference of $2-1=1$, or the effect of one current, is obtained—while in the wire that goes from station to station, one equal current neutralizes the other, and the effect is null; and we have therefore the further remarkable fact of two stations talking to each other, and no current passing from one to the other. I have not attempted the mechanical or electrical details of the instruments, which may vary, but have confined myself to the principle.

3. The system of sending *Time-signals*, by means of Shepherd's electric clocks, and under the direction of the

Astronomer Royal, Mr. Airy, has been brought to great perfection. A good compensating seconds' pendulum is the prime regulator of these signals. It is in the Royal Observatory, and is so hung that, in oscillating to the right, it makes contact with a spring, and sends a voltaic current through an electro-magnet; in oscillating to the left, it liberates a detent, or, in plain English, lifts up a latch, by touching a lever-arm. When the electro-magnet is made, it attracts a keeper, which by a simple mechanical arrangement lifts up a small weight; the weight is caught by the latch or detent and held up. When the latch is lifted at the left limit of the pendulum's oscillation, the weight falls and gives the pendulum a gentle tap. This slight tap, received at each vibration, keeps the pendulum in constant motion, as long as there is a voltaic battery connected and in action.

4. The pendulum sends seconds' signals to a dial or dials, by touching a spring at each limit of its vibration. These two springs are so connected that, when one is touched, a current is sent round electro-magnets in the dial in one direction; and when the other is touched, a current is sent in the other direction. All this is mere matter of arrangement. Facing the poles of the electro-magnets of the clocks are bars of steel magnetized; and according as the alternate currents come, the bars oscillate up and down like a see-saw, second by second. The same axis that carries the magnetized bars, carries also a pair of pallets, which work in a scape-wheel, connected in the usual way with a clock-train; and thus time is shown by an electric clock. Several clocks are readily placed in the same circuit, as at Greenwich, Tonbridge, Exeter, Paddington, and elsewhere; and each of these clocks, by means of its oscillating bars, may make contacts and itself send signals to another given number of clocks; and so on *ad infinitum*. The electric clock at Greenwich sends signals to the London Bridge Railway Station, and keeps an electric clock in motion there. The greatest distance that has yet been tried between the pendulum and a clock, was from the Royal Observatory, Greenwich, to the London Institution, Finsbury Circus, about six miles. We had a clock going, at this

distance, from the prime-motor, on the table during a lecture delivered there; and, by not violating the laws of resistance, the action may be far more widely propagated.

5. Of the clocks moved in this way at the Royal Observatory, there is one fitted up with means of sending a signal every hour along various circuits prepared to receive it. These are the veritable *time-signals*, which are sometimes manifested by deflecting needles; at other times, by dropping time-balls. The wire, that is to receive these signals, enters the clock on one side and goes out on the other; but is divided in three places as it passes the clock, which places are represented by three pairs of springs, all of which must be respectively pressed together before a signal can pass. Small insulated pins, carried respectively on the minute, the hour, and the twenty-four hour wheels, are employed for this purpose. The minute-wheel makes connection every minute, the hour-wheel every hour; but unless the other wheel also connects up, either at a given hour or at every hour, no signal can pass: it does this at all hours but 1 P. M., having twenty-three pins for this purpose; and twenty-three hourly signals are daily sent in this way to the London Bridge Railway Terminus; and thence, by means of the electric clock above mentioned, they are directed either to Dover, to Chatham, or to the Strand, according to a prearranged plan; to Dover at 12 and 4 P. M., to Chatham at 3 P.M., and the rest of the hours to the Strand. The wire from Greenwich for the greater part of the day is resting on the Strand wire, and the signals are free to pass; but at 12 and 4, it is lifted off and placed on the Dover wire, which has also been raised from its place of rest; and at 3, it is in a similar way connected with the Chatham wire; in each case being held on for about 1½ minute; and this is done automatically by the clock movement.

6. Figure 6 will give a general idea of the arrangement at Greenwich. The battery *b* is connected with the earth E on one side; and from the other side a wire leads to the clock, which is broken in three places, *m*, *h*, and *a*; the springs at *m* are pressed together, by a pin in the minute-wheel, at the sixtieth second of every *minute*; those at

h, by a pin in the hour-wheel, at the sixtieth minute of every *hour*; those at *a*, at *all* hours but 1 P. M. The

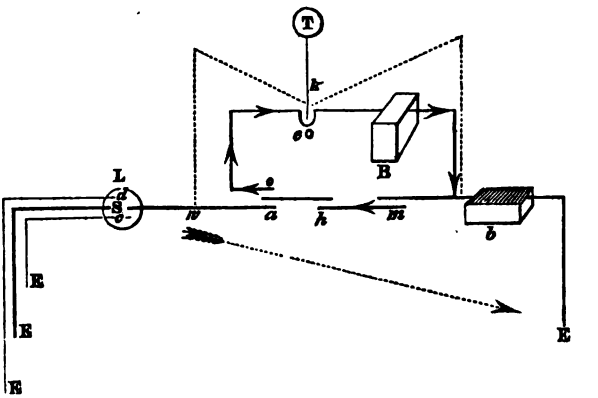


Fig. 6.

contacts at *a* and *h* are held on a short time; that at *m* occurs when the time is due for the signal, and is broken again the next second. L is the London station, and S, *d*, and *c*, the wires leading respectively to the Strand, to Dover, and to Chatham; and according as the Greenwich wire is on one or other of these, the signal passes and the discharge of the other end of the battery occurs at one of these places.

7. It has been the custom to drop the time-balls in England at one o'clock; hence the time-signal at that hour is not sent from Greenwich as the rest are, but is guided differently. A pin differently placed corresponds with 1 P. M., and completes a circuit *o* of another battery B, leading to a powerful electro-magnet *e*, whose keeper is connected with the trigger, by which the Greenwich time-ball T is held up; when the time arrives and the current passes in this circuit as marked by the arrows, the keeper is attracted, the trigger is pulled and the ball falls, and is visible to the captains on the Thames, and for miles around. The keeper of the magnet *e* not only draws the trigger of the Greenwich ball; it also connects two springs at *k* in such a manner that the battery

b is simultaneously put into connection, as shown by the dotted lines, with the wire *w* leading to the Strand; and thus the ordinary 1 P. M. hour signal goes to the Strand, at which place it is received by an electro-magnet, which, by a lever system, is connected with the trigger of a time-ball there; this trigger is pulled, and the ball falls, and in falling starts a clock, which had previously stopped at 1 P. M., being a little fast.

8. The keeper at Greenwich, in its attraction, puts also a distinct set of batteries in connection with a distinct wire, not shown in the drawing, leading to London, and thence connected, at 1 P.M., with the wire leading onward to Deal, where a time-ball is ready raised. The current actuates a small electro-magnet at Deal, which puts a battery there in connection with a larger electro-magnet, the keeper of which pulls the trigger and so allows the Deal ball to fall. This ball is visible to the shipping in the Downs. When nearly down, or in from $\frac{1}{4}$ to $\frac{1}{2}$ a minute after starting, the ball touches a lever, and sends back to Greenwich a signal, which notifies that the drop has truly occurred. The wires for this purpose are lent by the South Eastern Railway Company, for a couple of minutes or so every day; and, at the respective junctions, are connected up into the necessary order and again replaced, by means of electric clocks. The clock at London receives its time, second by second, from Greenwich; those at Ashford and Deal are local electric clocks, similar in principle to the prime-motor clock at Greenwich. Certain of the wheels are furnished with pins, which act, like those at the Observatory, upon certain springs for a minute before and after 1 o'clock, and connect the London wire at Ashford with the Deal wire, and the railway wire at Deal with the wire that leads to the ball-drop in the Navy Yard there.

9. In order that these two clocks shall do their duty at the right time, neither of them too soon or too late, which would be fatal to the object in view, they are daily corrected by the same time-signal that drops the ball. They are allowed to gain a few seconds daily, and thus to arrive at one o'clock a little too soon; they

stop at one. This is managed by causing the clock to make a supplementary circuit, at one o'clock, through which so much of the battery current shall pass, that what remains in the proper circuit shall not have power enough to make the clock go. This circuit is made by three pair of springs and three pins on their respective wheels, as in the Greenwich clock, all of which contacts only occur at 1 P.M., and then the battery circuit is diverted from the clock, just as if a wire had been led from *w* to E in the direction of the dotted arrow in the figure, at the time when the three contacts existed, which would have prevented any current passing along towards L.

The time-signal, on its way to Deal, passes through a small electro-magnet in these clocks; the keeper is attracted, and lifts a spring, which breaks the supplementary circuit, and the clock immediately starts at true time, and will not stop again till the same hour next day.

10. In the illustrations we have thus given of methods of sending language and time by electricity, it must not be supposed that we have exhausted the subject. Out of the abundance of material before us, we have merely selected the specimens that were most calculated to illustrate the broad principle. We have not even ventured to enter upon the more practical parts of the subject, and to show how much of the great results are due to the skill and ingenuity that have been displayed in the management and the insulation of the wires; how, if suspended, they are held up by earthenware, porcelain, or glass, wrought into the shapes that comply with the best theoretical conditions; how, if buried or submerged, they are coated with a most perfect insulator, gutta percha, applied with consummate skill; and how they are further protected in iron pipes or wooden troughs, or if submerged are shielded in jackets of iron-wire.

C. V. WALKER.

Modern Fortification and Siege Operations.

BY J. H. STOCQUELER.

LESSON I.

MODERN FORTIFICATION.

1. THERE is scarcely a science of such great antiquity as fortification, and for the simple reason—that it springs from an instinct of our nature—the doctrine of self-preservation. Few persons have ever found themselves playing in an apartment with a child armed with a stick, without observing that, if a feint is made to resent the infantine attack, the child will run behind a chair or a table, and thus, conscious of its security, defy the adult. The same principle governs the masses occupying great towns liable to hostile assaults. They shelter their concentrated abodes behind one common wall.

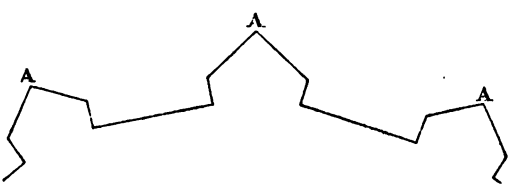
2. In the earliest records with which we are familiar—the Holy Bible—we read of many fortified towns; and as we follow history to later periods, we find the system of entrenchment continued with modifications and improvements adapted to ages when gunpowder was unknown. The usual plan of the ancients was to raise lofty walls of great thickness, with ditches in front, and towers at certain intervals. Sometimes there were double walls or retrenchments, with a second ditch between them, and beneath each tower was a gate strongly barred and guarded. The ditches were often scarped to make their inner sides difficult of ascent, and palisades were driven into the escarps with sharpened projecting points to offer obstructions to an enemy. On the battlemented towers machines were placed, for the purpose of propelling stones and javelins upon the heads of besiegers. Moreover, a series of dams and dykes was constructed in the neighbourhood, the sudden removal of which, enabled the besieged to flood the encampment of hostile armies, and compel their retreat.

3. The invention of gunpowder introduced a new element in defence. Strength of wall, represented by

height and thickness, became the less necessary, because the cannon shot kept an enemy farther from the works, and put an end to battering-rams, moveable towers, and other appliances of attack. Besides, as the invention was as useful to the assailants as to the besieged, it became of importance to reduce the surface of wall exposed to the shot of the beleaguering army.

4. But although the alterations in the structure of fortresses, arising out of the use of ordnance, were necessarily numerous, it was not until the close of the seventeenth century, that a system of fortification was introduced which comprehended every variety of defence against the assaults of artillery. This was originated by Vauban, an engineer officer of remarkable talent, who flourished in the reign of Louis XIV. of France. Vauban directed all the sieges by the French army in Spain and Holland, not less than fifty-three in number, and was present in 140 actions, yet, strange to say, he was never employed in the defence of a place. He however constructed thirty-three fortresses, and was engaged in the repair and improvement of no fewer than 300 forts and posts. It was probably his experience of the ease with which places had been taken which suggested the improvements he originated.

5. Vauban's system of fortification consisted of a continued wall or parapet, elevated twenty-two feet above the level of the country or plane of site, called technically the *terre-plein*, and entirely girdling the town. This rampart was divided into *curtains* and *bastions*. In the olden time the bastions were circular. Vauban gave them the form of an angle, connected with the curtains or straight parts of the wall by flanks; thus

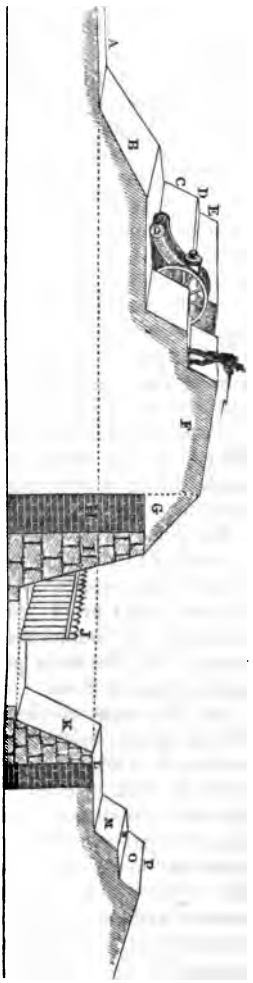


the distance of the salients (A) from each other he made

invariably 360 yards, so that if the space to be enclosed was considerable, the number of bastions might be proportionately increased without weakening the effect of musketry defence. The construction of the bastions insures a cross fire upon an enemy; and as the range of musketry was computed at 180 yards, a body of troops assaulting the centre of the curtain would be exposed to equal damage from the fire of either face of the bastions. The space between two bastion salients or projecting angles is called a *post;* and as the distance comprehended in that interval is always the same, a fortress, octagonal in form, would protect a town 2880 yards, or nearly a mile and three-quarters, in circumference.

6. Around the fortress, and following the sinuosities of the bastions and curtains, Vauban dug a ditch thirty feet in depth and ninety feet in breadth. This ditch supplied the earth of which the ramparts were composed, but in order to impart solidity to the structure, a *revetment*, or support of stone and brickwork, faced the ditch on either side, and extended for twelve feet beneath the earthwork of the escarp, and eight feet of the counterscarp. The rampart was so ingenious in form, and so consonant to the exigencies of defence, that it has been preserved intact by later engineers, and may be traced in every fortress in the United Kingdom and the British dependencies. It will be understood by the annexed diagram (p. 331). A represents the line of country or surface on which the fortress is built. B, a slope of earth called the ramp of the *terre-plein of the rampart:* it leads to an artifical flat surface, twenty-four feet in depth, from which rises the parapet for the protection of the soldiery. C is the *ramp*, which leads to and supports D, the *banquette* or bank, on which the infantry stand to fire over the parapet: E is the *inner slope*. These three slopes are merely intended to sustain the superincumbent earth. F represents the *superior* slope. An inclination of three feet is given to it, that the fire of the soldiery may be directed upon the *glacis* P, should the enemy approach that point. G is the *exterior slope*, designed to support the superior, and H and I exhibit the manner in which the whole mass is

sustained by brick (H) and stone work (I). J is a stockade or strong paling, which defends the centre of the ditch. K is the *counterscarp*, so called because it faces the *escarp*. L is the *covered way*, M the *ramp*, supporting N the *banquette* (as in the interior of the rampart); O the inner slope, and P the crest or upper edge of the *glacis*, which slopes outward to the country for a distance of fifty yards, so as to give to the defenders of the fortress a greater command of the enemy.



7. All this comprehends the main outline or *enceinte* of the fortified town. But there are several outworks in Vauban's system, of considerable strength, and, when occasion requires, temporary structures are raised, which encrease the resisting power of the fortress. In front of the *curtain* is placed a *ravelin*, or angular work, 100 yards in depth, and of still greater breadth at the back, or gorge, constructed exactly upon the same principle with the bastion, and surrounded by a ditch 20 yards in breadth. This ravelin is an effectual protection of the ditch. The covered way, which runs all round the outer part of the fortress, is further defended by *traverses*, parapets eight feet in height, which are placed across it, for the double purpose of receivng the splinters of the shells of a besieging army, and enabling the infantry

to maintain a running fight on the covered way when the town is assaulted.

8. Between the curtain and the ravelin, in the main ditch, is raised another angular work (the angle towards the curtain), termed a *tenaille*, because it has some resemblance to a pair of pincers. The French, from whom we derive the greater portion of these terms in fortification, are addicted to the use of familiar words, whenever the works bear any resemblance to a familiar object. Thus we have *lunettes* (spectacles), *flèches* (arrow-heads), *mamelon*, a corruption of *mamelle* (the breast); and others descriptive of field-works, to which we shall hereafter allude. The tenaille is connected with the ravelin by a passage protected by a parapet, and called a *caponnière*.

Within the bastions are sometimes raised loftier works termed *cavaliers*, and the ravelins have occasionally a *redoubt*, or elevated defence.

Fortresses are sometimes surrounded by wet ditches. When this is the case, there is no tenaille in the ditch, but a drawbridge connects the curtain with the ravelin.

Such are the permanent defences of a fortified town, according to the plan of the first of French engineers. Other men — such as Cormontaigne, Montalembert, Cohorn, and Carnot—have improved upon the system by additions of numerous impediments to a besieging army; but the main principles of Vauban have never been departed from.

9. The guns employed in the defence of a town are of the largest calibre. As they are not required to be moved, it is unnecessary to consider lightness and portability in their construction. The long guns range from 32 to 68 pounders—so called from the weight of the shot they carry. Mortars, also, are placed at convenient intervals on the ramparts, and from them are propelled the *shells*—hollow balls of iron half filled with gunpowder and sand. A *fusée*, filled with an inflammable composition, is placed within the shell, and this being united by the gunpowder, which constitutes the charge the mortar, it burns while the shell is in its flight,

communicating its flame to the contents of the shell, just as the point aimed at has been reached. The shell then explodes, scattering its deadly splinters, or broken parts, in every direction. It is hardly necessary to say that the fusee is cut to a length suitable to the distance the shell is destined to travel.

10. As the *embrasures* (the apertures in the parapet for the reception of the muzzles of the guns) are cut so as to give the guns a command of every point of the surrounding ground, it is difficult for a besieging army to place its batteries in any direction without being more or less exposed to the fire from the garrison. This is one and the principal of the impediments offered to the assailants; but they are likewise exposed to the sallies or sorties of the garrison. The object of these sorties, which are often made in great strength, is to kill the gunners, destroy the batteries, and *spike* the guns. The latter operation is effected by means of a small implement, about four inches in length, and of the thickness of a tobacco-pipe. It resembles a nail in its flat top; but at the other extremity is a barb, which, on being forced into the vent, expands, and is thus incapable of being withdrawn; so that the effect of the sortie has been to disable a gun and retard the siege operations.

11. Another form of defence is the mine, or countermine. The defenders are accustomed to make excavations between the face of the outside (or counterscarp) of the ditch and the approaches of the besiegers. A train of gunpowder being conveyed in hose, called *saucissons* (because they correspond in diameter with sausages), to the ditch, the opportunity is taken when the works of the enemy have advanced near the crest of the glacis to ignite the mine and blow up the batteries. The communications between the inner part of the fortress and the dry ditch is through a sloping subterranean passage, seven feet high, called a *postern*, which has steps six feet from the ground, at its termination, and which, being on hinges, are susceptible of being drawn up when an attack is contemplated, and of thus forming a gate, or barrier, against the ingress of the enemy.

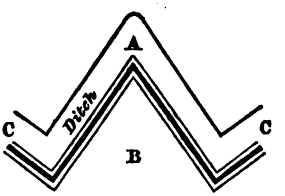
12. In this description of a fortress we have confined

ourselves to the system of Vauban and its modifications. The enduring defence of Sevastopol has, however, introduced us to a new element in fortification, and a controversy has arisen respecting its merits. Mr. James Fergusson, an architect of great taste and profound reflection, some time since broached an opinion that a fortress composed entirely of earth, of much greater depth and thickness than ordinary walls, and composed of a series of terraces or parapets, rising one above another, each armed with heavy ordnance, and in form circular, instead of angular, would prove more formidable than any of the structures of the Vauban school. Sevastopol, being in some degree thus fortified, has been regarded as establishing, in its stubborn resistance, the correctness of Mr. Fergusson's theory; but the opponents of the system contend that Sevastopol was not besieged upon the recognized principles of the science, and that, therefore, the question has never been fairly tried. The town at no time was entirely surrounded. The garrison received continual reinforcements, and were enabled by their energy and well-directed labour to build up the parapets as fast as they were knocked down.

13. In the foregoing sketch we have considered only what is called *permanent* fortification, that is to say, the fortification of towns by an *enceinte continuée*. Temporary, or *field* fortification, is another and not less useful branch of the science. It passes by the general term of *entrenchment*, for the simple reason that the *trench* or *ditch*, which is cut along the front, in the first defence, supplies the earth of which the protecting parapets are constructed. These parapets, which correspond in form with those of the fortress, vary in depth with the time allowed for their construction, or the known strength of the artillery of the enemy. The ordinary computation is, that a parapet of eight feet in depth will resist the shot of 6-pounder guns, which only bury themselves in two-thirds of the parapet. For 9, 12, and 14 pounders a thickness of from twelve to fourteen feet is desirable. Guns of heavier calibre are seldom used in the field, as they are difficult of transport.

14. The field-works take a variety of forms, adapted to the character of the country, the position of the force to be entrenched, its liability to attack, and the nature of the object to be defended. The most common form is the triangle. Such is the shape of a *redan*, a *lunette*, and the flanking projections of a *redoubt*, or field-fortress. The advantage of the angle is, that it presents two faces to the surrounding country. The angle itself is the only weak point, and therefore it is protected by flanks and a variety of obstacles placed opposite the salient—the part usually selected for attack.

Annexed is a horizontal outline of a redan. A is the *salient;* B, the *gorge*, or inner part of the work; C, the *flanks*.



15. The artificial, or extra means of resistance placed in front of the redan are the *abattis*—young trees eighteen to twenty feet in length. Stripped of their leaves, their branches shortened, the outer ends sharpened, and the trunks driven into the ground, the trees thus projecting outwards constitute a formidable obstacle to an attacking force. Preference is given to the young tree, because the quantity of sap which it contains makes it much more difficult to cut it or burn it than would be the case with a dry or withered tree. Beyond the abattis, which are often partially concealed by earth raised in front of them, are dug *trous-de-loup*, or wolf-holes, so called from the resemblance they bear to the pitfalls with which the French peasantry in the olden time were wont to catch the wolves which then abounded. These *trous-de-loup*, or military pits, as they are more commonly termed, are shaped like funnels. They are made seven or eight feet deep, and in the centre of each is placed a stake sharpened at the point. A body of soldiers, rushing to attack a redoubt or redan thus protected, would infallibly be caught in these pits, or brought to a standstill by the abattis; and while in that perplexity the occupants of the work

they are proceeding to attack would gall them with their musketry.

The other obstacles are placed on the faces of the ditch. They are *palisades*, or palings, as we should familiarly say, driven firmly into the escarp and counter-scarp, and projecting at a slight angle—the latter obstruct the descent into the ditch, and the former offers a barrier to the ascent. In additions to these, rows of palisades are placed erect in the middle of the ditch, or across it at the angles, and these are called stockades.

16. In the defence of villages and farm-houses, the entrance to streets, and the passage of bridges, every advantage is taken of the loose materials at hand to construct barricades and parapets. Logs of wood, casks, sacks of earth, carts, brick-walls, cotton-bales, woollen-packs, tables, chairs, bedsteads, hampers, piled up and connected with loose earth, form capital obstacles and protection against musketry. The windows of houses are likewise broken, and the pillows and mattresses placed in their apertures to receive the bullets of an enemy, and protect the defenders, who will also loophole the walls of the building and the gardens.

LESSON II.

SIEGE OPERATIONS.

1. The motives for obtaining possession of a given fortified town are numerous. It may be that the town contains an arsenal and ample *matériel* of war which it is desirable to destroy; or it defends the approaches to a country which the hostile force may be desirous of possessing; or represents the heart and vitals of an empire; or is essential as a base of operations; or commands the passage and obstructs the navigation of a river; or, like Sevastopol, is a sort of pirates' nest, where ships are built and equipped for aggressive purposes. To capture and destroy such a town, if fortified, a very systematic plan of operations is essential. A large park of artillery, comprising guns of every

kind and calibre, a force of infantry, a body of engineers, and a proportion of cavalry, are indispensable, guided and commanded by an experienced chief.

2. Approaching such a town, the commander sends out a party to reconnoitre its form and strength, and to ascertain the points of egress. The object of knowing the latter is, that a sufficient force may be at once so placed as to intercept the garrison if it made any attempt to escape. The main body then advances and invests or surrounds the town at all points. This is effected by digging a trench three or four feet in depth and fifteen feet in breadth, at a distance of five or six hundred yards from the walls of the fortress, and placing *gabions* (cylindrical baskets three or four feet in length, and a foot and a half in diameter), filled with the earth displaced from the trench to a sufficient height and thickness to protect the working parties from the fire of the garrison. This point accomplished, and the trenches occupied by the infantry, the engineers then proceed to construct the batteries—in other words, to establish platforms of small boards in the rear of certain parts of the parapet, and to open embrasures for the reception of the muzzles of the guns which are to be employed in the siege. The line of trenches thus formed is called the first parallel, because it runs parallel to the contour of the fortress. Parties of cavalry are picketed at either end of the parallel, protected by mounds of earth called *épaulements*, to prevent surprises and flank attacks. The infantry who occupy the trenches keep their attention constantly directed towards the fortress, in order to be prepared at a moment to repel any sorties, and to watch their opportunities of shooting the artillery of the garrison who may show themselves at the embrasures or above the parapets of the fortress.

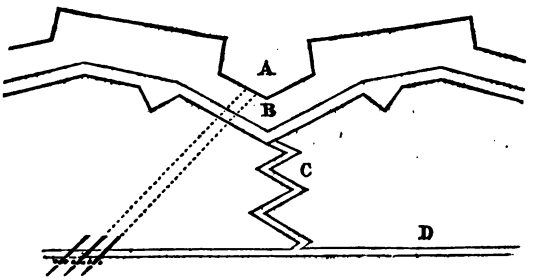
3. The batteries are so placed, that they may command the weakest and most exposed parts of the fortress, and *enfilade* them—in other words, sweep the covered way with a fierce cannonade. Should there be any reason to suppose that an army will march to the relief of the garrison, and endeavour to compel the assailants to

raise the siege by attacking them in the rear or diverting their attention, a line of *circumvallation* is formed. This consists of an entrenchment in the rear of the besiegers sufficiently at hand to enable the besiegers to desist from their work and assemble at any point that may be threatened. The works which defended the Allies at Sevastopol to the south and east of their position, while they directed their attention to the city in the north, were in the nature of a circumvallation.

4. When the first parallel has been completed, the second is commenced from one hundred to two hundred yards nearer to the fortress. But, to reach the point where the second parallel is to begin, it is necessary to proceed carefully and under cover. A trench is therefore dug in a zigzag form in the direction of the *salients* of the bastions of the fortress, because this method secures the approach from the most mischievous effects of the fire of the garrison. The construction of the second parallel proceeds upon the same principles as those which governed the formation of the first; but inasmuch as the nearer approach of the besiegers brings them more completely under the fire from the fortress, the loss in killed and wounded necessarily becomes greater. It is at this stage of the siege that the assailants send forth riflemen to seek or create cover for themselves, the latter being effected by digging pits for their reception, at a distance of fifty or one hundred yards from the embrasures of the parapets, and thence annoying the artillery of the garrison at their guns. It is now also that the sorties of the besieged become more frequent. Having a smaller distance to traverse, they are the better enabled to retreat with rapidity after they have damaged the batteries and guns of the besiegers.

5. The third parallel, embracing a much narrower circle, is commenced after the completion of the second, and from this point the siege proceeds with vigour, and the intensity of the defence is proportionately multiplied. From the third parallel, the engineers *sap up* to the salients—in other words, they cut zigzag trenches in

the direction of the salients, for the double reason that they are less exposed to an enfilade or a raking fire, and approach the weakest point of the fortress.



6. The sappers and miners now begin to perforate the earth, and to construct subterranean galleries, in order to enable them to get into the ditch shielded from fire, and undermine the escarp. In this difficult and dangerous operation, they have been frequently known to encounter parties of the garrison working their way to establish counter-mines beneath the batteries of the besiegers, and serious subterranean conflicts here take place. At length the trenches have been brought close up to the covered way. Parapets are then raised to give the infantry a protection, while raking the covered way and clearing the ramparts with their musketry. The guns being brought up as near to the counterscarp as possible, the bombardment commences, with a view to breaching the salients and other parts of the bastion or wall in the curtain. Against the fortresses in the Peninsula of Europe, it was found that a continuous bombardment of from forty-eight to sixty hours, involving the consumption of 20,000 shot and shell, sufficed to lay bare a sufficiency of the walls to afford ingress to the besiegers. At Sevastopol, a bombardment of the fiercest nature, lasting for four or five days, and proceeding from 400 pieces of artillery of large calibre, was essential to the due breaching of the principal works—the Malakoff Tower and the Redan.

7. When the breach has been established, the time has

arrived for *storming* the fortress. Volunteers are called for to form the forlorn hope—the *enfans perdus*, as the French call the devoted body, who are to lead the way in the attack. There is never any deficiency of volunteers on these occasions; a natural enthusiasm, a desire for distinction, appears to animate the whole army. It is more difficult to know whom to reject than whom to accept. This party—accompanied by sappers and miners and working parties who carry ladders, sandbags, and *fascines*, and *saucissons*, bundles of faggots of various lengths bound very tightly together—leads the way when the moment arrives for the attack, descending the ditch and hastening to ascend it amidst a storm of musketry, grape, *hand-grenades* (small shells thrown from the hand), and *camouflets*, a description of fireballs emitting a suffocating odour. The forlorn hope is rapidly followed by the battalions; and it is seldom that the garrison, however stoutly it may fight, is not overpowered by the assailants. The latter, however, have by no means an easy task. The interval between the establishment of the breach and the assault, has generally been filled up by the garrison in the preparation of other defences, such as *chevaux-de-frieze* (long bars forming a centre or axle whence radiate projecting spikes, sword-blades, bayonets, or spear-heads), traverses, gabions, and so forth, from behind which they are enabled to pour musketry upon the assailants. At the sieges of Badajos and Tarifa, in Spain (1811 or 1812), these impromptu defences caused great loss to the attacking parties, and in the latter case effectually saved the town.

8. Penetrating the defences, the assailants drive the garrison to surrender, unless there should happen to be a citadel or strong and lofty castle within and overlooking the town which affords a final refuge. As the ramparts are gained, the guns are either spiked or turned upon the town and citadel, and this latter falling to the persevering attacks of the besiegers, the garrison capitulates, and is marched out with or without the honours of war,—drums beating, colours flying, and bayonets fixed,—according to the discretion of the general commanding the besieging army. Where much gallant

resistance has been manifested, and nothing is to be apprehended from allowing the garrison to retain their arms, the honours of war are generally allowed. The most notable instance on record of this mark of respect being shown to the garrison occurred at the siege of Minorca, in the last century, when the 23rd Royal Welsh Fusileers and three other regiments behaved so nobly that the Duc de Richelieu, a chivalrous commander, awarded them the highest honours, and published a complimentary order.

J. H. STOCQUELER.

Astronomy.

BY ROBERT MAIN.

LESSON I.

THE MOON.

"It shall be established for ever as the moon, and as a faithful witness in heaven."

1. THE Moon being so near to the earth, the study of her motions becomes not only interesting as connected with the theory of astronomy, but absolutely necessary for many of the purposes of ordinary life. In the earlier ages of the world, before the science had sufficiently advanced to allow of an accurate knowledge of the motion of the sun, the synodical period of the moon, that is, the interval between two successive new moons, afforded a good and sensible measure of time, and the festivals of the Jewish calendar depended upon the observation of the phenomenon or *phasis* of the new moon. In the early periods of Egyptian history it is also supposed that the dynasties of the kings were reckoned in *lunar years*, that is, in months; since, on the supposition of the years mentioned in the ancient chronicles of that kingdom being solar years, it seems absolutely impossible to reconcile the accounts there given with those derived from any other sources, sacred or profane.

2. In modern astronomy, however, the use made of th

motions of the moon is of a totally different and of a much more important kind. The science of navigation is based almost exclusively upon it and upon mechanical arrangements by chronometers for exhibiting an equable measure of time. To accomplish the first of these objects the Royal Observatory of Greenwich was instituted in the reign of Charles the Second; and for the advancement of the second, large rewards were offered by the Government in the last century for the encouragement of artists in the construction of clocks and chronometers. In both these objects the success of British enterprise and British science has been so complete that it may be, without boasting, asserted, that if no other nation had ever taken part in the practical part of the important problems connected with nautical astronomy, the science would still have been brought, by Englishmen alone, to its present state of perfection. It is due, however, to the French nation to state, that though even the correct physical theory of the motions of the moon is due to our immortal countryman, Newton, yet the analytical development of the theory is due almost exclusively to La Place and Le Grange, and to other eminent Frenchmen.

In these lessons it is proposed to give some account of the lunar orbit; of the eclipses of the sun and moon, which occur with tolerable frequency on account of the small inclination of their orbits; and, finally, of the analogous phenomenon of the transits of inferior planets over the disk of the sun.

3. It has been before mentioned that the orbit of the moon is described in a plane which cuts the sphere of the heavens in a great circle, and that on account of the small variations of her apparent diameter during a revolution, she must describe a curve round the earth not greatly different from a circle. If, for example, we were to measure her angular diameters throughout a lunation, we should find that the greatest was about 33′ 30″, and the smallest about 29′ 30″. In the first case the moon is said to be in *perigee*, or nearest the earth; and in the second case, in *apogee*, or thest from the earth. The difference between the

greatest and least diameters proves that though the orbit does not deviate very much from a circle, yet that this deviation or *excentricity* is still considerable, amounting as it does to about one-eighth part of the whole. The proportion of the greatest and least distances will, in fact, be in the inverse proportion of the greatest and least apparent diameters, that is, as $\frac{1}{33\frac{1}{2}}$ to $\frac{1}{33\frac{1}{2}}$, or as 67 to 59. Now the most obvious supposition to account for this circumstance would be, that the orbit is an ellipse of small excentricity. Our readers will generally be acquainted with the nature of this important curve, but, for the benefit of those who are not acquainted with it, we will define its leading properties.

4. In the figure, let F and G be two fixed points in the straight line A B, P any point in the curve; then, if the curve be the ellipse, the sum of the lines F P and P G for every point will be of a constant length. If through E, the middle of F G, C D be drawn at right angles to it, then A B is called the major axis, C D the minor axis, and C the centre of the ellipse.

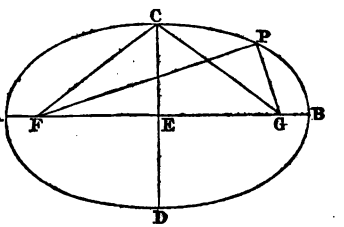


Fig. 13.

It is almost self-evident that the major axis will be equal to the constant sum of F P and G P, and consequently to F C and G C. Hence A E will be equal to F C. This is called, in planetary orbits, the planet's *mean distance*, being half the sum of the greatest and least distances F B and F A. The ratio $\frac{FE}{EA}$ or $\frac{FE}{CF}$ is called the excentricity of the ellipse.

5. Let us now apply this to the case of the lunar orbit, which we will assume to be an ellipse. The ratio of the greatest and least distances is, as we have seen, 67 to 59, hence the *mean distance* may be represen

by half the sum of these, or by 63, and the *excentricity* by F E divided by this quantity. But F E is equal to the mean distance diminished by the least distance. Hence the excentricity is $\frac{63-59}{63}$, or to $\frac{1}{16}$ nearly. This may then be taken to represent the average value of the excentricity of the lunar orbit, though on account of the disturbances to which the moon is subject by the action of the sun, neither this nor any other element has a constant value.

By observing the positions of the moon when her diameter has its greatest and least values, that is, by observing her right ascensions and declinations, and computing from them her longitudes and latitudes, we should find the positions of the *perigee* and *apogee*, and therefore the direction of the major axis of the orbit. The direction of this line is called the line of *apsides;* and by observing it through several revolutions of the moon, we should find that it has not a fixed position, but has a *progressive* but variable motion, of such rapidity that it goes through the whole circle in about nine years.

6. It has been before stated that the mean or average inclination of the plane of the lunar orbit to the ecliptic is about 5°, it will therefore cut the ecliptic in a diameter of the sphere; the point where it cuts it as the moon is ascending from south to north latitude being called the *ascending node*, and the other point of intersection the *descending node*. By observing the moon at times a little preceding and a little following the time of passage through the nodes, it is found that these points are not fixed, but have a *retrograde* motion in the heavens of such a nature as to complete a whole revolution in about 18½ years. The inclination of the orbit also is not constant, but varies from about 5° to 5° 17′.

7. Into the general theory of elliptic motion of the planets we cannot enter; but we can state, as the fundamental law of it, that the *planets describe round their central bodies equal areas in equal times.* In consequence of this they move *slowest* when at the *greatest distance*, and move *fastest* when they are *nearest* to the bodies about which they are revolving. We may also

add that the *angular velocity*, which may be considered nearly to represent the increase of longitude, *varies inversely as the square of the distance.*

In the lunar orbit, however, these laws are only approximately obeyed, on account of the disturbances produced by the sun; and after calculating a place of the moon according to the elliptic theory, it is necessary to apply several other corrections, many of which are of considerable amount, to deduce the true place.

8. After considering the form of the lunar orbit, the next point for consideration is the size of it, or, which amounts to the same thing, the mean or average distance of the moon from the earth; and this introduces us to another important subject, namely, the fundamental unit of lineal measure. In England this unit, to which all other lengths are referred, is the yard; and recently very laborious efforts have been made by astronomers to verify the standard yard of commerce, and to produce a considerable number of indisputably exact copies. That this can be done, and that, if necessary, we could exactly define the length denoted by a *yard*, must be for the present taken for granted, though the subject is one of very great difficulty, and has exercised the abilities of some of the greatest mathematicians of Europe.

9. By actual measure of portions of the earth's surface at different times, the magnitude of the earth has been ascertained with very great accuracy in terms of this unit; and, according to Mr. Airy, its dimensions are as follows:—

Equatorial diameter = 7925·648 miles.
Polar diameter = 7899·170 miles.

Each mile containing 1760 yards, or linear units, before referred to.

It appears, therefore, that the equatorial exceeds the polar diameter by 26·478 miles, or by $\frac{1}{299\cdot471}$ part of the equatorial diameter.

This is called the earth's *ellipticity* or *compression*, and the nearest approximate value of it in whole numbers is $\frac{1}{300}$. Without sensible error we may therefore

assume the compression to be $\frac{1}{300}$, and this result should be carefully remembered.

10. The equatorial diameter of the earth being then expressed in units of an intelligible quantity, namely, the yard, may be used as the unit wherewith to compare the distances and diameters of the other planets; and the distances thus represented, present to the mind a much more intelligible idea than when represented, as they usually are, in miles. Thus, it is much easier to have a correct notion of the real distance of the moon, when we are told that she is distant from us 60 semi-diameters of the earth, than when told that she is distant 240,000 miles; and this applies still more forcibly when applied to the distances of the sun, and the planets revolving round him.

11. We will now endeavour to show how the distance of the moon is ascertained; and to do this the more readily, we will first consider how the distances or heights of unapproachable objects on the surface of the earth are measured. Every one at all acquainted with trigonometry knows that this is done by first measuring a base, judiciously chosen with reference to the object, and then by observing the angles subtended by the object at its extremities. The case will still more nearly approximate to that of finding the distance of a heavenly body, if we suppose that the bearings of the line joining the extremities of the base, and of those joining each extremity with the object, be observed with reference to the cardinal points of the compass. If, for instance, the object were at a great distance, and we observed the angle made by a chosen point and the object with the meridian, and then measured the same from another point chosen on our base-line, these angles would differ by a small angle, which is equal to that subtended by the object at the extremities of our base. The object, with reference to the horizon, has therefore been *displaced* by this angle; and such displacement in astronomy is always denoted by the term *parallax*.

12. To determine then the distance of the moon, or any other heavenly body, it is necessary to find her *parallax*,

or apparent displacement in the heavens, when viewed at opposite extremities of such a base as we are describing. For instance, let M be the centre of the moon; C the centre of the earth; and C E the projection of an equatorial radius of the latter.

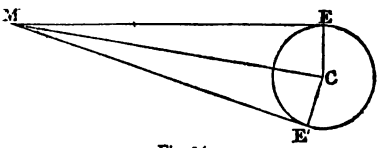


Fig. 14.

Then the angle E M C will be the angle of displacement relatively to the base C E; and, supposing C E M to be a right angle, is called the moon's *horizontal equatorial parallax*. This, however, cannot be measured immediately, since the point C, or the centre of the earth, is unapproachable; but, if we could station two observers at opposite sides of the equator, as at E and E′, then the whole displacement would be represented by the angle E M E′. This, however, would be a displacement in right ascension, which, for reasons which cannot be detailed here, is not capable of eliciting the moon's parallax so correctly as observations of her polar distance. The object will, however be obtained equally well if two stations be chosen on the earth's surface, one in a high northern latitude, and the other in a low southern latitude, the base for measurement being the distance between them; and the parallactic angle, the angle subtended by the moon at its extremities. The farther apart are the stations, the larger will be the angle of parallax; but it must be remembered, that the determination requires observations of first-rate excellence, and such only as can be made in fixed observatories, with large meridian instruments.

13. Let then P and P′ be places on opposite sides of the equator, and on the same meridian, and imagine the earth to be spherical. (The introduction of the ellipticity of the earth, and the corrections necessary to be made in the observations, to reduce to the same meridian, would only render the problem more complicated, and may be omitted in the general explanation.)

Let also p and p' be the north and south poles of the earth opposite to each other. Then Z C p and Z' C p' are the colatitudes of the places of observation, and if M be the moon, and C P and C P' be produced to Z and Z', M P Z and M P' Z' will be the apparent zenith distances of the moon as affected by parallax. But the sum of these latter angles is evi-

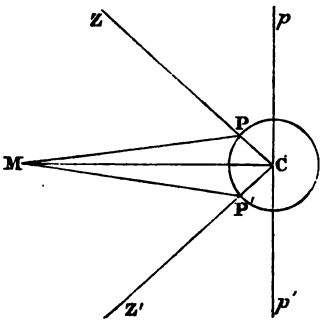


Fig. 15.

dently equal to the sum of the geocentric zenith distances Z C M and Z' C M, together with the parallactic angle P M M'; and, finally, the two geocentric zenith distances, together with the colatitudes, are together equal to two right angles, as is manifest by the figure.

Hence, the parallactic angle P M P' is equal to the sum of the two observed zenith distances, together with the colatitudes, diminished by two right angles; and is therefore capable of being measured by observation, since, in the case of the moon, it considerably exceeds a degree of arc.

To obtain from this the equatorial horizontal parallax, it is necessary to investigate the law according to which the parallax or displacement of the moon varies for different altitudes above the horizon.

For this purpose let us fix our attention on the triangle P M C, in which it is evident that the angle P M C represents the moon's parallax, for the distance C M, and for the apparent zenith distance Z P M. We have then, by plane trigonometry,

$$\frac{\text{Sin P M C}}{\text{Sin Z P M}} = \frac{\text{P C}}{\text{M C}} = \frac{\text{earth's radius.}}{\text{moon's distance.}}$$

$$\text{Hence sin P M C} = \frac{\text{earth's radius}}{\text{moon's distance}} \times \text{sin apparent}$$

h distance; or, sine parallax $= \frac{\text{earth's radius}}{\text{moon's distance}}$

+ sine apparent zenith distance or sin parallax = $\frac{\text{earth's radius}}{\text{moon's distance}} \times$ sin apparent zenith distance.

If now the moon be in the horizon, the sine of apparent zenith distance becomes equal to unity. Hence sin hor. parallax = $\frac{\text{earth's radius}}{\text{moon's distance}}$, and therefore sine parallax = sine hor. parallax × sin apparent zenith distance; the parallax of the moon, then, at different heights, if her distance remain the same, varies as the sine of apparent zenith distance, and by this rule, combined with the equation above deduced from observation, the horizontal parallax of the moon for a given time can be determined, and by observations thus made at Greenwich and the Cape of Good Hope, her parallax has been very accurately determined and tabulated.

LESSON II.

ORBITS OF MOON AND EARTH—TRANSITS.

"They shall fear Thee, as long as the sun and moon endure throughout all generations."

1. One of the most important elements in any orbit is the time of revolution, since upon this, in addition to the mass of the central body, the magnitude of the orbit exclusively depends. The time of revolution of the moon, or the period, is either *tropical*, or *sidereal*, or *synodical*, or *anomalistic*. The *tropical period* is the time which elapses between the departure of the moon from the first point of Aries, and its return to it; the *sidereal period* is the interval between the departure from, and the return to, the same point in the heavens; the *synodical period* is the time between two successive conjunctions with the sun; and finally, the *anomalistic period* is the time between the departure from and return to the apogee, or point of the orbit farthest from the earth.

2. The period which admits of most direct determination is the tropical, because the places of all bodies are referred to the equinox, and, on account of the rapid motion of the moon, the interval of time for a great number of revolutions can easily be obtained; and

hence, by dividing by the number of revolutions, the mean time of one revolution can be very exactly obtained. In this way, by means of observations extending over a century, it was found that the daily mean motion of the moon is 13° 10′ 35″, and hence that the time of a tropical *revolution*, that is, the time of describing 360°, is 27 days, 7 hours, 43 minutes, and 5 seconds, nearly.

3. If the equinox were fixed, that is, if the point of intersection of the ecliptic and the equator always occupied the same position in the heavens, the time of a tropical would be equal to that of a sidereal revolution; but this is not so. By comparison of ancient and modern observations, the equinox is found to have a retrograde motion (that is, contrary to the sun's motion), amounting to about 50″ annually. The fact observed in the comparison is, that while the longitudes of all stars are increased by the same quantity, the latitudes remain very nearly the same; hence it is evident that while the ecliptic has remained sensibly fixed, the earth's equator has been moving upon it with a retrograde and uniform motion. This fact can be accounted for by the supposition, proved by theory to be correct, that the pole of the equator describes round the pole of the ecliptic a small circle, whose radius is equal to the obliquity, that is, to 23° 27½′, at the rate of 50″ in a year, completing, therefore, its circuit in about 26,000 years.

4. The phenomenon now explained is called the *precession of the equinoxes*, from the circumstance of its causing the sun to return to the equinox sooner than it would otherwise do; and thus making the *tropical year*, on which the return of the seasons depends, shorter than it would otherwise be. From this explanation it will be easy to calculate the length of the sidereal period of the moon from the tropical, for, assuming the exact quantity of the *annual precession* to be 50″·224, the moon will, in returning to the equinox, describe $360° - \frac{50''\cdot224}{13}$; while, in returning to the same point of the heavens, she will describe 360°, and,

therefore, the sidereal period will be longer than the tropical, in the proportion of $360° : 360° - \frac{50''\cdot224}{13}$, or, in the proportion of $1\cdot00000300 : 1$, or by $\frac{1}{333333}$ part nearly. Hence the tropical revolution being equal to $27^d\ 7^h\ 43^m.\ 5^s$, or to 2360585 seconds, the sidereal revolution is evidently longer, by about 7^s, and is equal to $27^d\ 7^h\ 43^m\ 12^s$.

We might also reason thus:—In a revolution of the moon, of which there are thirteen in the year, the equinox recedes by $\frac{50''\cdot224}{13} = 3''\cdot862$. But, the moon's mean daily motion being $13°\ 10'\ 35''$, her motion in one second of time is $\frac{1}{86400}$ of this, or $0''\cdot549$, and the time of describing $3''\cdot862$ will be $\frac{3''\cdot862}{0\cdot549}$, or 7 seconds nearly, as before.

5. To determine the mean *synodical period* of the moon, we must consider how much the sun has been carried forward in his orbit during the time that has elapsed between one conjunction and the following. The synodical period will thus be greater than the sidereal in in the proportion of 360° to 360° plus the sun's motion the synodical period. Hence the synodical period will be to the sidereal period as 360° to 360° diminished by the sun's motion in the sidereal period. Assuming the sun's daily mean motion to be $59'\ 8''\ 33$, it will be found that the *synodical period* of the moon is $29^d\ 12^h\ 44^m\ 3^s$, very nearly.

Knowing the mean value of the progression of the apogee, we might, in like manner, show that the anomalistic period is equal to $27^d\ 13^h\ 18^m\ 37^s$; but enough has been given to familiarize the student with the method of computing the different values of the periods of the moon from the tropical period.

6. Before proceeding with the subject of eclipses, it will be necessary to have correct notions respecting the

sun's orbit, or, to speak more strictly, of the orbit of the earth.

This orbit, like that of the moon, is excentric, the sun being nearest to us in winter, and farthest from us in summer. The line of apsides has also a small progressive motion, amounting to about 12″ in a year. The mean daily motion of the sun has been before stated to be 59′ 8″·33, which arc he describes in 3^m $56^s \cdot 555$ of mean solar time. This, therefore, is the difference between a sidereal day and a mean solar day; and from the above data, no difficulty will be found in expressing sidereal intervals of time in terms of mean solar intervals, or in determining the length of the sidereal year and of the anomalistic year from the length of the tropical year, which consists of 365^d 5^h 48^m 47^s.

7. As the size of the lunar orbit is found by observation of the moon's parallax, so the distance of the sun from the earth, and the size of the solar orbit might apparently be measured by means of the sun's parallax. But there is this important difference in the two cases, that whereas the parallax of the moon amounts to nearly a degree of space, and therefore the rudest observations made at suitable places on the earth's surface could scarcely fail to elicit an approximate value, the parallax of the sun is very small, not amounting, at its maximum, to 9″, and therefore would require observations of the utmost accuracy to give any approximation whatever to the truth. Indeed, by observations of the sun directly the parallax could not be detected, but we are enabled to bring into play a curious law, which governs the motions of the planets round the sun. This law, together with two others, was discovered by the great astronomer Kepler, and the three are known generally under the name of *Kepler's laws*. They are as follows:—

1. The planets describe round the sun elliptic orbits, having the sun in one of the foci of the ellipse.

2. They describe round the sun equal areas in equal times, thus moving fastest when nearest to the sun, and slowest when farthest from him.

3. The squares of their periodic times are proportional to the cubes of their mean distances from the sun.

8. It is with the latter of these laws alone that we are concerned at present, and its use in investigating the sun's parallax will be quickly made evident.

The sidereal periods, or the periodic times of the planets, have been long since found, from observation, with considerable accuracy; and, by the application of Kepler's third law, the ratios of their mean distances are, therefore, known with the same degree of accuracy. The excentricities and positions of their orbits, with respect to the ecliptic, are also well known; and, therefore, the proportions of the distances of any one of them from the earth and from the sun, that is, the ratio of the solar parallax to that of any of the planets at a given time, can always be calculated.

If, then, by any means we could accurately determine the difference of the parallaxes of the sun and planet, the absolute value of each would be determined.

9. Now the planet Venus offers occasionally, though rarely, means for determining the difference between her parallax and that of the sun by her transits across the solar disk, and these phenomena are eagerly watched for and observed by astronomers whenever they occur. The inclination of the orbit of Venus to the ecliptic is very small, not greatly exceeding 3°, and hence it is plain that transits across the sun will occur occasionally, just as eclipses of the sun and moon occur frequently on account of the small inclination of the lunar orbit. If the plane of the orbit of Venus coincided with the ecliptic, for example, there would be a transit across the solar disk at every inferior conjunction of the planet; but as this is not the case, there will be a transit only when the latitude of Venus at the time of inferior conjunction is less than the sun's semidiameter, and when, consequently, she is near the node of her orbit. The limiting value of the distance of Venus at the inferior conjunction, which will render a transit barely possible, can therefore be readily calculated, since, neglecting the diameter of Venus, her latitude must be equal to or less

than the sun's semidiameter, or to 32′, neglecting the effects of parallax.

10. Knowing when the last transit of Venus happened, it will be easy to predict the number of years which must elapse before the next will occur. For, since Venus is then near the node of her orbit, it is plain that, to bring the earth and the planet again into the same relative situations, each must have described a complete number of revolutions. Now, the sidereal period of Venus is about 224·7 days, and that of the earth is about 365·25; hence, to determine approximately the intervals of time which must elapse between successive transits, we must find the smallest numbers expressing the proportions of these periodic times. These numbers are respectively 8 and 13, 235 and 382, 713 and 1159, &c., eight revolutions of the earth occupying as much time as thirteen revolutions of Venus, Now the last transits happened in the years 1761 and 1769, when Venus was in the descending node; hence the next transits at the descending node may be expected in the years 2004 and 2012, at the interval of 235 years. The last transits at the ascending node occurred in 1631 and 1639, and we may expect the next at the same node in the years 1874 and 1882. These will happen in the lifetime of many of our readers, and will form important epochs in the history of Astronomy.

11. We will now endeavour to explain generally how the transit of Venus is rendered available for the determination of the solar parallax.

Let P and P′ be two stations on the earth's surface, one having a high northern latitude, and the other a low southern latitude; *v* V *v′* a portion of the orbit of Venus moving in the direction of the arrow-point. The velocity of Venus is considerably greater than that of the earth, and if we suppose her to be moving with the difference between her own velocity and that of the earth, we may suppose the latter to be at rest. To an observer at P, the transit will begin at the point *b* on the sun's disk, in the line joining his own position with that of the planet, and the first impression will be the appearance of a small dark notch, or indentation in the

limb of the sun, which is observable with great accuracy. This observation is called the *first contact*; and

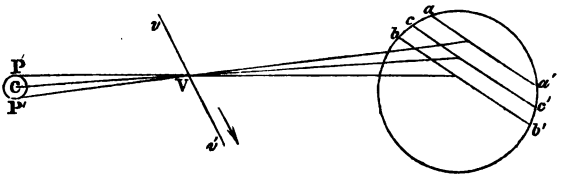


Fig. 16.

the observation of the *second contact*, when the following limb of the planet is fairly on the sun's border may be also made, but probably not with so great accuracy. The planet will now be seen like a small black ball on the sun's disk, and in its progress will describe the sensibly straight line $b\,b'$ across it. Similarly, an observer at P′ would see the planet describe the line $a\,a'$, while at the centre of the earth the line $c\,c'$, intermediate to the other two, would be described. Now, in the transit of 1769, Venus was coming to the descending node, and had north latitude, and the lines $a\,a'$ and $b\,b'$ were above the sun's centre, and the chord $b\,b'$ considerably larger than the chord $a\,a'$, and hence the time of describing $b\,b'$ was considerably greater than the time of describing $a\,a'$. Hence the duration of transit for the position P was greater than for the position P′.

12. Now, this difference of duration depended evidently on the *difference of parallax* of the sun and Venus, since the point a of the sun's limb was apparently depressed by a quantity depending on the sun's parallax, and the same point representing the apparent position of Venus was depressed by a quantity depending on the parallax of Venus. If Venus and the sun had been at equal or very nearly equal distances from the earth, then each would have appeared equally displaced by parallax, and the lines $a\,a'$ and $b\,b'$ would have coincided with $c\,c'$. The difference of position of these lines is therefore an effect of the difference of parallax of the sun and Venus, and gives an exaggerated measure of it. By properly conducting the observations and calculations, it may there-

fore be found in terms of known quantities. But the ratio of the parallaxes is also known from the proportion of the mean distances, since the parallax of each is inversely proportional to the distance of each from the earth, and the distance of Venus from the earth at the time of the transit, is the difference of the mean distances of the earth and Venus from the sun.

13. Thus far it has been supposed that the whole parallactic effect on the duration of transit, as observed at different places, is produced by the relative parallax of the sun and Venus in the direction of a meridian of the earth, that is, from north to south, and we have left out of sight the effect produced by the earth's rotation from east to west. This, however, is too important a feature to be omitted; and the choice of stations for observation depends very much upon the effect of parallax in this direction. Imagine, for instance, two places in the same latitude, but on opposite sides of the globe, in longitudes differing by about 12 hours, or 180°. As the planet is approaching the sun from east to west, by her relative orbital motion, a line drawn from the easterly position through the planet will pass nearer to the sun than a similar line drawn from the westerly position, and hence the first contact will, to the eastern observer, take place earlier than to the western observer; and if the planet be near setting to the eastern observer, it will probably not long have risen to the western observer. But as the earth revolves, it may before the end of the transit, which occupies six hours, be again above the horizon of the eastern observer's position in the east, while it is past the meridian of the other place of observation. A line now drawn through the planet from the eastern observer's position will therefore meet the sun farther from the western border than a similar line drawn from the other observer's position, and the transit will therefore commence earlier, and terminate later, than for the other, or the duration will be increased.

14. This important point had been well studied previously to the transit of 1769, and the most successful observations were made at two places, Wardhus and Otaheite, admirably situated to give the best possible

results. Wardhus is in Lapland, its longitude being about 29° east of Paris, and its latitude 70° north. Otaheite, to which our celebrated countryman, Captain Cook, was sent, is about 152° west of Paris, and in 17½° south latitude; and hence, both on account of the great difference of latitude and of longitude combined, the duration of the transit, as observed at Wardhus, was rendered almost as much greater than that observed at Otaheite as the circumstances of the case would admit of.

The results deduced from the duration of the transit at places properly situated, are independent of the longitudes of the places of observation; but it is evident that, supposing the longitudes to be well known, comparative observations either of the ingress or the egress of the planet may be made available. The failure of the results deduced from the transit of 1761, from which Halley predicted great accuracy, was mainly due to want of accurate knowledge of the longitudes of the observing stations.

15. The most probable value of the solar parallax, as deduced by Professor Encke from a rigorous discussion of all the observations, is 8″·58 very nearly, and it is not likely that this result will be altered by any significant quantity by any future investigations.

It may be desirable to state in this place that by the solar parallax is meant the angle which the earth's radius would subtend at the distance of the sun; and since the value of the earth's radius is very accurately known by measurements made at the surface, the sun's distance can be immediately calculated, and is about 95,300,000 miles.

16. Mercury, being an inferior planet, also passes across the solar disk, when very near to the node of his orbit at inferior conjunction; and this phenomenon occurs more frequently than for Venus, on account of the shortness of his period of revolution. The last transit occurred in 1848, and was extensively observed; and the next will occur in the years 1861, 1868, and 1878. The transits of Mercury are of comparatively small importance for the determination of the solar parallax, the planet's distance from the sun being only 36,000,000

miles; and, therefore, the distance from the earth being 59,000,000 miles, which is too large for an accurate determination of the parallax by observatious made at distant stations.

The student will now, it is hoped, be familiar with the way in which the dimensions of the lunar and the solar orbits have been ascertained with such precision, and will be better prepared for understanding the description of the eclipses of the sun and moon, to which, in a great measure, the following lessons will be devoted.

LESSON III.

ECLIPSES OF THE SUN.

"I will cover the sun with a cloud, and the moon shall not give her light."

1. THE consideration of solar eclipses will naturally take precedence of that of eclipses of the moon; and the preceding discussion on the transit of Venus will tend to familiarize the student with the principles necessary for understanding the circumstances under which these phenomena must happen. From our preceding investigations, it appears that the orbit of the earth round the sun is about 400 times larger than that of the moon round the earth; the mean radius of the former being about 95,300,000 miles, and the radius of the latter being about 240,000 miles. The mean value of the lunar parallax, that is, the angle under which the earth's radius would be seen from the moon, being about 57′, and the moon's angular radius being about 15¾′, it follows that the real diameter of the earth and moon will be in the proportion of these numbers, or nearly in the proportion of 11 to 3. Now, the diameter of the earth, as we have seen, is about 7,900; and therefore the diameter of the moon is about 2,200 miles. The diameter of the sun being about 885,000 miles, it thus appears that the diameters of the sun and moon are as 400 to 1, very nearly, that is in the proportion of their distances from the earth. Hence it follows that the average angular diameter of the moon, as seen from the earth, will be about

equal to the angular diameter of the sun. On account, however, of the excentricity and inequalities of the lunar orbit, the angular diameter of the moon is sometimes considerably greater, and sometimes considerably smaller than that of the sun.

2. We can represent this fact by an illustration which will be very useful in facilitating the conception of the theory of eclipses. Imagine the sun and moon to be enveloped by a conical surface. The shape of this surface will be, to use a familiar similitude, like the extinguisher of a candle, and will, of course, terminate in a point; and the interior of the surface will touch the spherical bodies of the sun and moon. If the surface be produced, another similar surface will be found in the opposite direction, having the same point, or *apex*, as it is usually called.

Now, if the moon were to preserve a constant distance from the earth, then whenever she came to inferior conjunction, that is, in nearly a straight line between the earth and sun, this *apex of the cone* would, from what has been said, just reach the earth; but, if the moon were to be at this time farther from the earth than the mean distance, near *apogee* for example, and therefore nearer to the sun, then this *apex* would not reach so far as the earth; and finally, if the moon were near perigee, or nearer to the earth than the mean distance, the apex of the cone would lie beyond it.

3. Now, it is evident that no light whatever from the sun can reach any part of the interior of this cone between its apex and the moon; and therefore if, when the moon is near perigee, and in conjunction with the sun, she be also so near her node, that is, so near the ecliptic, that a portion of the earth's surface is crossed by a part of the section of this imaginary cone, then it is plain that no light from the sun can reach this part of the earth's surface, or, for all the regions over which the moon's shadow thus sweeps, there will be *a total eclipse* of the sun. For regions in the neighbourhood of the zone where the eclipse is total, only a portion of the light from the solar disk can reach the earth, and the eclipse will be *partial*.

4. If, on the contrary, the moon is near *apogee* at the time of conjunction, and also very near her node, then the *apex* of the cone will not extend so far as the earth, and a portion of the earth's surface, situated very near the point where the axis of the cone produced meets it, will experience what is called an *annular eclipse*, that is, for a short time only a minute ring of the exterior portion of the solar disk will be visible. For if this point be supposed to be the apex of another cone enveloping the moon and extended to the sun's surface, it will evidently cut it in a circle concentric with the solar disk, and, for parts of the earth's surface very near this, the circle will be very nearly concentric. The limiting boundaries of the regions where an annular eclipse is visible are, however, very confined, and near the boundaries, through imperfections even now existing in the lunar tables, it would be impossible to predict beforehand whether the eclipse would be annular or partial. Cases also occur when the angular diameters of the sun and moon are so nearly equal that it is impossible to predetermine accurately whether the eclipse will be annular or total; or, in other words, whether the apex of the cone enveloping the sun and moon will be between the moon and earth or extend beyond the latter.

The extent of the earth's surface over which an eclipse will be total, or over which it will be annular, will depend on the difference of the angular diameters of the sun and moon, and on the proximity of the moon to the node at the time of conjunction.

5. It has been stated that eclipses happen only when the moon at the time of conjunction is near the node of her orbit. The distances of the moon from her node within which it is possible for an eclipse to happen is called the *lunar ecliptic limit*; and according to calculations founded on the best modern tables, this distance is about 18½°.

6. In calculating the circumstances of a solar eclipse, it is evident, from what has been said, that it is necessary to determine generally whether an eclipse will take place at all, on any part of the earth's surface; secondly, whether it will be total or annular for

any points; and lastly, to trace geographically the line of totality or annularity, and to determine the circumstances of the eclipse for certain important stations, where it may be well observed in fixed observatories. Let us suppose the eclipse to be total for some parts of the earth, then the apex of the cone will lie beyond the earth's surface, and the central line of the totality will be traced out by the intersection of the axis of the cone with the surface of the earth, while the breadth of the section of the cone intersected by the earth will determine the dimensions of the zone of country over which the eclipse will be total. This evidently admits of exact calculation from a knowledge of the motions of the sun and moon; and in cases where the line of totality extends over large portions of the civilized globe, and especially over Europe, it is a problem of so much interest and importance, that maps are constructed with great care previously to its occurrence, showing the boundaries of the total eclipse, and observers are despatched by the scientific bodies of different countries, to the places where it can be best observed.

7. Within the last few years two important total eclipses have taken place, the one in 1842, when the line of totality extended over a great portion of southern Europe, and the other in 1851 (after half a revolution of the moon's node), when it passed over the northern countries of Europe. Both were admirably observed by several of the most celebrated astronomers of modern times, and have elicited some remarkable discoveries as well as many suggestions for turning to the best advantage future opportunities of observing similar phenomena.

8. Independently of the interest which attaches itself to solar eclipses on account of the grandeur of the physical circumstances with which they are attended, and of the knowledge which they furnish concerning the surface of the sun, they are also of very great importance in the ordinary theory of astronomy. In the first place, they furnish means for correcting the elements of the lunar and solar tables by comparison of the predicted time of contact of the limbs of the sun and moon with

the observed time of contact. The time at which the limb of the moon will, at a given place on the earth, appear to be in contact with the sun, can be accurately calculated on assumed elements of the orbits of the sun and moon. But that the calculated time should agree with the observed time, it is necessary that the elements both of the solar and the lunar orbit should be accurately known, and especially the moon's longitude, latitude, and horizontal parallax. Any error in one of these elements will produce a disagreement between the observed and calculated times; and, conversely, the observed disagreement will furnish equations for the correction of the lunar orbit, assuming the solar orbit to be correct.

9. At the present time, when observations of the moon can be made with so much accuracy by means of the large instruments of fixed observatories, the eclipse observations are not of so much importance as formerly; but they are still of consequence in this respect, that they furnish an observation of the moon relative to the sun at a time when the latter body is generally incapable of being observed.

10. Eclipses of the sun are also useful in determining the longitudes of distant places. To understand their use in this respect, it is necessary to understand in some degree the principles of the various methods of determining terrestrial longitudes in general. Imagine two meridians of the earth's surface, differing by a certain number of degrees which it is required to find. If there be fixed observatories at these places, the local time at each place, whether it be reckoned by means of the sun's hour angle, or of that of the first point of Aries, that is, whether it be mean solar time or sidereal time, is determined fundamentally by means of transits of stars across the meridian. Let us suppose the time to be sidereal, and therefore to represent the hours, minutes, and seconds expressed in parts of a sidereal day, which have elapsed since the first point of Aries crossed each meridian. The difference of the true sidereal times at two places for any given instant of absolute time be therefore equal to the time occupied by the

first point of Aries in passing from one meridian to the other, that is, it will be equal to the difference of longitudes. If then by means of any phenomenon, which could be observed by the clocks or chronometers at the two stations at the same instant of absolute time, we were able to obtain the local sidereal times corresponding to this instant, we should thus obtain immediately the difference of longitudes of the two stations.

11. For very short distances, this has been frequently accomplished by means of rocket-signals from one of the stations visible at the other, or by flashes of gunpowder. For very considerable distances, the difference of longitudes has frequently been found by carrying chronometers from one station to the other, comparing their indications of time immediately before their departure from the one, and immediately after their arrival at the other, and depending upon the average steadiness of their rates during the passage. Still more recently advantage has been taken of the facilities afforded by the electric telegraph by completing the circuit of the wires between any two observatories whose difference of longitude is required, and then observing the very nearly simultaneous deflections of a galvanic needle at each of them. By this latter process the longitudes of all the principal observatories in Europe will shortly be determined with an accuracy unattainable by any other process.

12. However, in defect of any of these processes, recourse must be had to observations of celestial bodies, and if amongst these any can be found which happen at the same instant of absolute time for every place on the earth, they will correspond exactly to the case last mentioned of the deflections of the galvanic needle, and are of course to be preferred to any others. Such phenomena are the eclipses of Jupiter's satellites; and, if they could be accurately observed on shipboard, they would be very valuable for determining the longitude at sea. On account, however, of the motion of the ship, this is almost impossible, and it is necessary to determine the longitude at sea by other methods.

13. The method which is found most practicable for this purpose is that of lunar distances, that is, the observa-

tion of the distances of the moon from the bright fixed stars, at every available opportunity. The moon, indeed, circling amongst the stars, answers the purpose of a clock in the heavens, if we consider the stars whose positions are well known as the hours and minutes marked at fixed intervals on the dial-plate, and the moon as the travelling index which records the time (*absolute time*) for the use of all by whom she is visible. The difference is chiefly this, that in the case of an ordinary clock no skill is required either to read or to interpret the result; but in the case of the moon, a delicate astronomical observation is required in the first place, and in the second, laborious and refined astronomical calculations to deduce the result.

14. The difficulty of the computation arises from the allowance which it is necessary to make to the observed distance on account of refraction and parallax, to reduce it to that which would be observed at the centre of the earth, for the purpose of comparing it with that deduced from the distances given in the 'Nautical Almanac' for small and regular intervals of Greenwich mean time. But, notwithstanding the difficulty of the computation, the method is the only practicable one which can be depended on at all times for obtaining longitudes at sea, and is therefore absolutely necessary to be studied and practised.

15. We now come to another class of phenomena available for determination of longitude, namely, eclipses of the sun. In this case the phenomenon is not simultaneous at the two stations; but the time of its occurrence, that is, the time of first or last contact of the limbs of the sun and moon, depends on the longitudes and latitudes of the places of observation, as may be gathered from what has preceded.

Thus supposing the latitudes of two stations to be the same, an eclipse of the sun would happen earlier at the more westerly of two stations than at the more easterly, because, by means of the moon's parallax, she is projected on the sphere of the heavens farther towards the east, than she would be at the more easterly station, and therefore, as she is going in her orbit from west

to east, she will apparently meet the sun sooner: supposing, then, that the elements of the lunar and solar orbits, as well as the latitude of the place of observation, are known accurately, but that the longitude is known only approximately, then since the computed time of the contact of the limbs of the sun and moon estimated in Greenwich time could be erroneous only through an error in the assumed longitude, it is evident that, by properly arranging the calculations, means could be found for expressing the difference between the observed and the predicted time, in terms of the error of longitude, and for thus determining the value of the error.

16. The moon in her progress through the heavens sometimes *occults*, or passes over a star, and, this being a phenomenon which can be observed with great accuracy, and which may be regarded as of the same class as eclipses of the sun, it is evident that occultations of stars when observed at different places will also afford means for determining their difference of longitude. The calculations necessary in this case, as well as in the preceding, are complicated and difficult on account of the moon's parallax.

LESSON IV.

ECLIPSES OF THE MOON.

"Thy sun shall no more go down; neither shall thy moon withdraw itself: for the Lord shall be thine everlasting light."

1. We now come to the subject of eclipses of the moon. These are occasioned by the interposition of the earth in a direct line between the sun and moon, and must therefore happen when the moon is in opposition to the sun, or at the time of full moon. The moon must also, as in the case of eclipses of the sun, be near the node of her orbit, the ecliptic limit, beyond which an eclipse cannot take place, being about 12°.

2. The general theory of eclipses of the moon is easily rendered intelligible, by means of the same illustration as that already used in the case of eclipses of the sun. Imagine a conical surface to envelop the bodies of the sun and the earth: then this surface, when produced,

will have its apex or point at a considerable distance beyond the moon; and the frequency of eclipses and the magnitude of the ecliptic limits will depend on the area of the section of this cone, at the distance of the moon at right angles to its axis, that is, to the line joining the sun and earth. Now, the radius of this section is very easily calculated from our knowledge of the dimensions of the solar and lunar orbits, and of the diameters of the sun, moon, and earth.

3. The mean radius of the solar orbit is, as we have seen, about 400 times that of the lunar orbit, and the diameter of the earth is to that of the moon, as 11 to 3 very nearly; and finally, on the same scale, the semi-diameter of the sun would be 1210, being 110 times that of the earth. Hence the distance of the apex of the cone from the earth will easily be found (by consideration of the similar triangles formed by a section of the cone passing through its axis) to be to the radius of the solar orbit as the semi-diameter of the earth, to the difference of the semi-diameters of the sun and earth, that is as 1 : 109; and therefore the distance of the apex from the earth is very nearly four times the distance of the moon from the earth.

4. It will perhaps conduce to clearness to illustrate this by a diagram:—Let N S N′, and A E A′, repre-

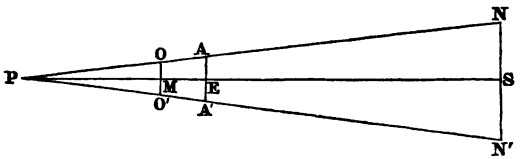


Fig. 17.

sent diameters of the sun and earth, N P N′, the section of the enveloping cone through the axis P S; M, the centre of the moon for a central eclipse, and O M O the diameter of the section of the cone at M.

Then the distance E S is 400 times the distance M E, and the semi-diameter N S is about 110 times the semi-diameter E A.

Now by similar triangles,

$$PS : PE :: NS : AE$$
$$:: 110 : 1$$

and therefore—

$$PS - PE : PE :: 110 - 1 : 1$$
$$:: 109 : 1;$$
$$\text{or, } ES : PE :: 109 : 1$$
$$\text{Hence, } PE = \frac{ES}{109}$$
$$= \frac{400 \text{ times } EM}{109}$$
$$= 4 \text{ times } EM \text{ nearly.}$$

It is evident, therefore, that—

$$OM = EA \times \frac{PM}{PE}$$
$$= \text{three-fourths of earth's radius}$$
$$= 3000 \text{ miles nearly.}$$

This is nearly three times the radius of the moon, and gives the magnitude of the section of the shadow, within which no light from the sun can fall on the moon, or within which the eclipse of the moon will be total.

If part of the disk of the moon project beyond O or O′, then the eclipse will not be total.

5. The preceding investigation has shown the breadth of the section of the shadow of the earth, within which *no* light of the sun can fall, and this is called the *umbra*, to distinguish it from the *penumbra*, within whose boundaries only a portion of the light of the sun can fall.

To illustrate this, we shall need a diagram.

Let S, E, and M be respectively the centres of the sun, the earth, and the moon; N C C′ N′, a portion of a section of the conical surface enveloping the sun and earth passing through the axis, S E M. Then the space A C C′ A′ will be totally dark, and as long as the moon is within the space, no light can fall upon her. Draw now tangents N A′ B′ and N′ A B on opposite sides of the sun and earth: then it is evident that, if the moon be in the line B A N′ or B′ A′ N, the whole of the light of the sun will reach her surface, but if she

be at points P P′ within the space B A C or B′ A′ C′, then only the light from portions of the solar disk,

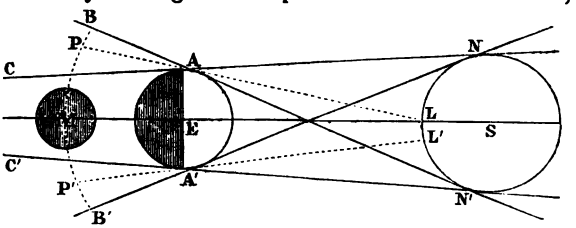


Fig. 18.

defined by the tangents to the earth, P A L and P′ A′ L′ will reach her, and each of these partially darkened spaces is called the *penumbra*. At the first entrance of the moon into the penumbra, very little difference of brightness is perceived on her surface; but the obscuration becomes greater as she approaches the boundary of the umbra, after which a portion of the disk becomes invisible, and, in the case of a total eclipse, the enlightened portion becomes less and less till the whole disappears.

6. Even when the moon is totally immersed in the shadow, her disk is still faintly visible, though in some cases it requires a tolerably exact knowledge of her position in the heavens to detect her: the colour of her disk at this time is that of dulled or tarnished copper. This singular effect is generally attributed to the refraction of the rays of the sun in their passage through the densest parts of the earth's atmosphere as they graze the surface of the earth. That refraction would cause the rays to be reflected towards the *umbra*, we may easily prove, and it is possible that they may be farther scattered by the small semi-reflective substances which they meet with in their progress, in a way analogous to that which produces the twilight.

7. Let E M be the axis of the conical umbra, and let R *r* be a ray of light passing very near the earth's surface. Draw the radius E *r*; then the ray on entering the atmosphere will be bent into the direction *r r′* nearer to E *r*, and, on passing out of it again, will be bent into

the direction r' r'' farther from E r', and, therefore, still nearer towards the axis E M, or towards the centre of the

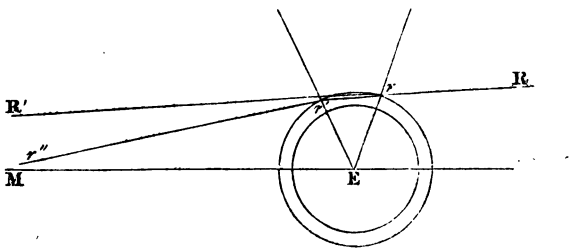


Fig. 19.

umbra. Hence if the rays be, in addition, scattered and dispersed by the motes and small substances floating in the atmosphere, so that on the whole the dispersion is still towards E M, it is easily conceivable that a sufficient quantity may fall upon the lunar disk to render it visible.

The degree of brightness of the surface of the moon is different in different eclipses, and in some eclipses several of the spots on the surface have been distinctly visible.

8. On account of the gradual immersion of the moon in the earth's shadow, it is extremely difficult, and we may say practicably impossible, to determine the precise instant when the first contact with the *umbra* takes place, and hence lunar eclipses are of comparatively small importance in practical astronomy. For example, they are for this reason utterly useless in determining the longitudes of distant places on the earth, since the accuracy of such determination depends on the degree of accuracy with which a phenomenon can be simultaneously noted at the two stations. On the other hand, the circumstances of a lunar eclipse are much simpler than those of a solar eclipse, since they are independent of the position of the observer on the surface of the earth, and, therefore, if the contacts could be accurately observed, they would afford an excellent means of determining longitudes.

9. The determination of longitudes of places is, how-

ever, effected with tolerable accuracy by the eclipses of Jupiter's satellites, which happen at the same instant of absolute time to every observer on the earth. The eclipse of a satellite is not, however, strictly speaking, an instantaneous phenomenon, but, though admitting of very much more accurate determination than an eclipse of the moon, takes place gradually. In fact the phenomenon is precisely of the same kind as an eclipse of the moon, as will be seen by considering the cause of it. Jupiter, being an opaque body, casts a shadow behind him, and the four satellites revolving round him in the same direction, in precisely the same manner as the moon does round the earth, will frequently be immersed in the shadow and become invisible.

The obscuration will, however, as in the case of the moon, be gradual, and the rapidity of it will depend upon the velocity of the satellite in its orbit. The eclipses of the first satellite, or that nearest the planet, are, therefore, best adapted for the determination of longitudes.

10. Since also the satellites are small bodies, equivalent (when seen through a telescope) to stars of the 6th or 7th magnitude, and become very faint previously to their disappearance, it is plain that a telescope of superior power will enable an observer to see it longer previously to its eclipse than an observer using a smaller telescope.

Hence in endeavouring to obtain the longitudes of places by eclipses of the satellites, it is of great importance that the telescopes employed should be of equal power. This method of determining longitudes is inapplicable at sea, on account of the motion of the ship rendering the observations too uncertain and difficult.

11. Before concluding this portion of our subject we may advert to another important use of solar eclipses, namely, that of determining chronological epochs. In ancient history we read of total eclipses of the sun, which had important influence on political events, from the dread which, in the absence of scientific knowledge, ich a mysterious phenomenon occasioned. Such an lipse was that which, according to the historian

Herodotus, put an end to a great battle between Cyaxares king of Media and Alyattes king of Lydia, and which is usually called the eclipse of Thales, from the circumstance of its having been supposed to be predicted by that philosopher.

12. We have here some data for identifying the eclipse, namely, the totality, and the portion of the earth's surface over which the shadow swept. Nevertheless, on account of the imperfection of the solar and lunar tables, which become very much exaggerated when used for calculating the relative places of the sun and moon backwards through so long an interval of time, the precise year in which this eclipse happened has always been a subject of dispute with astronomers. Till the present century the motions of the moon, and especially the secular variation of the mean motion, were too imperfectly known to decide any doubtful question of chronology in ancient history; and the first introduction to a better state of things was the publication of Burg's Lunar Tables by the French Board of Longitude. These were made the basis of a calculation of the eclipse of Thales by Mr. Baily in the year 1811, and he fixed upon a total eclipse which occurred on September 30 in the year 610 before Christ. In a recent paper, however, by Mr. Airy, the Astronomer Royal, he has found, by bringing into use the corrected elements of the moon's orbit deduced from his reduction of the ancient Greenwich observations, and by introducing, also, the additional inequalities recently discovered by Professor Hansen, that the eclipse of 610 will not satisfy the conditions required by the account given in Herodotus, and that it is much more likely that the eclipse referred to took place on May 28 in the year 585 before Christ.

13. In the same paper, Mr. Airy discusses with much learning and research another famous eclipse of antiquity, called the eclipse of Agathocles, which is mentioned by Diodorus and by Justin. For the most probable date of this eclipse he decides upon the morning of August 15, in the year 310 before Christ.

ROBERT MAIN.

Fine Arts.

LESSON I.

LAWS OF FORM.

BY JOHN BELL.

1. PARTLY concealed, partly visible, these laws are entwined with the powers and objects around us. Some portion may be demonstrated by reason, much can only be felt or expressed by refined taste. "To Kalon," or the beautiful, has been a fertile subject for the philosopher and artist from an early period, as soon as men were enough removed by the arts of civilization from the bare necessities of existence to snatch time for abstract subjects. According to the old mode of philosophy, theories are formed according to fancy, and the facts of nature are bent to agree with it. Inductive reasoning, which assumes nothing, but is guided by facts, is better adapted to lead to truth on the present as well as other subjects. In regarding the great scheme of nature, as presented to us in astronomy, balance of forces appears a great plan of the universe. The result of two forces, each of itself acting in a straight line, viz., the tangential force which drives the planets on in their course, and the force of gravity which holds them in their orbit, produces the various curves of the conic sections, which are all beautiful. The same balance of forces acts in the other effects of nature.

2. There are only two kinds of lines—the straight and the curved. From these simple elements all the forms of lines that exist are evolved. Various beyond expression, their results are seen in the infinite variety of forms of objects about us, and to the eye of thought are visible, sweeping through illimitable space in the straight lines of light and gravity, and in the vast curves of revolution in which worlds around, and far beyond our physical ken, are moving in a "wondrous maze but not without a plan." Nature has been said work by mathematics; all her effects are results of we call laws, which are the results of other laws

and causes which we know not. What we call causes, being only the result of other causes, and ourselves seeing nothing but effects, this is no reason why we should not search for such guiding principles as we may hope to arrive at. Subtle as the subject may be, we can only reach useful results on the firm footing of facts. In this frame of mind we will seek for those qualities which we find to exist in the objects which impress us with possessing beauty of form.

3. Among those qualities that mainly conduce to this pleasing effect of certain forms on us are fitness and proportion. We take these together, inasmuch as they have been theoretically put forward as containing and comprehending a full definition of all beauty. It has been attempted to define beauty as consisting in "a certain fitness and proportion." Everything in Nature is, no doubt, fit for its purpose, yet without perversion of terms we cannot call everything beautiful; and every combination of atoms may have a certain arithmetical proportion, but we cannot discover it, and therefore such a definition answers no useful purpose. Fitness is not a measure for beauty. The bear's form is as fit for him as that of the antelope, but it is not so graceful: the bulldog's figure is individually as fit as that of the Italian greyhound, but no one would compare them for elegance. We cannot deny great beauty in art to many arabesques, composed of elements impossible to coexist in nature, and therefore so far in the highest degree unfit; they are fit, however, for beauty. An angel, or human figure with wings on its shoulders, has been always allowed to be a beautiful form. All nations that have cultivated the art of design have delighted in representations that add the flight of the bird to the powers of man. Yet in none of these is there a structure of bones and muscles appropriate to render such pennons fit or useful. The term "proportion," also used broadly and unprecisely, is of no use in definition. Proportion, to be of use, must be exact and certain; and we are not sensible of any such existing in common in various objects. The proportion of the lily is not that of the rose, although they are both flowers, and both beautiful. So f

indeed, from there appearing to be one proportion in common for all objects, the direct reverse appears to be the case. Each animal, flower, and plant, seems to have a proportion peculiar to itself; no two objects appearing to possess the same ratio. Proportion in the human being varies with age, sex, and character. The proportions of beauty in a man, a woman, and a child are all various.

4. Although it cannot be rightly held that "fitness" and proportion contain and comprehend a definition of beauty, it is yet evident that they exist prominently in beautiful forms. Each part of graceful objects is fit for its intention, and in appropriate harmony, as the details of the form of the antelope or greyhound for speed and lightness; and the angelic representation should be endowed with the grace, power, and elegance of a superior intelligence. An eye is not beautiful unless clear, full, and perfectly formed for vision; and, as a general rule, the best-formed heads possess the best intellects. Experience and analogy teach us that an actual individual proportion peculiar to beauty in each object does exist. The lily and the rose—the oak and pine—though they do not present to us any rule of proportion common to all, yet have doubtless appropriate individual proportions in their finest examples. Throughout Nature we have reason to believe that individual proportions proper to beauty of form in each object exist, from the ratios of which they cannot much depart without at the same time relinquishing a portion of their beauty. The horse, the deer, the leopard, although their structures have great resemblances, yet vary extremely in their proportions, no common standard being at all adequate to represent them. On the other hand, each of these animals possesses an individual proportion proper for its individual perfection, a proximate knowledge of which at least is highly advantageous to an artist who desires to represent them, especially in sculpture, the effects and powers of which art are confined to the representation of Nature through her phase of form. In the
presentation of the human being, as the most studied
us, the rules of its proportions have been the nearest
ught to a definite ratio, modified however by age, sex,

and character. No rule and compasses alone will build up a figure—whence the saying of Michael Angelo, that no compasses equal those of the eye. As some of the proportions used by sculptors in regulating their statues may be curious and interesting to the general reader, I will extract a few as follows:—

5. The ancients observed that the human figure may be described within the square and the circle. When the feet are close together, the posture upright, and the arms extended in a parallel line, the measurement from the tips of the middle fingers, along the arms and across the chest, equals that from the sole of the foot to the crown of the head, or the whole height. The general observation was connected with the determination not only of the proportion, and position of the limbs and body by geometric lines, but also with the balance of the figure. When a figure stands upright, equally poised on both feet, the centre of gravity falls on a vertical line from the pit of the throat to between the two ankles. When the figure rests easily on one leg, the centre of gravity falls from the pit of the throat, between the outer and the inner ankle of the foot on which it rests. The general form of the head, viewed from the top, is circular, being however rather larger at the back of the head, and narrower at the forehead. The general view of the adult Greek head in front is egg-formed. In the profile, the simplest character, and the one adopted by the Greeks, is where the nose varies little from a straight continuance of the line of the forehead, the lips and chin being defined by small bends in and out, each about the quarter of a circle. In the Greek head, measured against a central line, the head and face are divided into four equal measurements, viz., from the top of the head to the roots of the hair, from the roots of the hair to a line passing through the eyes; from this line to the lowest part of the nose, and from this to the bottom of the chin. The legs in man should be at least equal in length to all the rest of the body. The Greek statues make them longer. In the female figure the legs are somewhat shorter in proportion. In the hand

each finger has its peculiar character, the middle finger being the only one that is quite straight: its supporters, the forefinger and the fourth finger, are about equal in length, and both lean somewhat towards the middle finger, as does also the little finger, which is the shortest of all. The thumb extends to the first joint of the forefinger. The foot is the length of the lower arm from the elbow and the axil bone: it should be arched, the instep forming the elastic arch on which the body moves and rests. The great toe is the strongest and broadest, but in beautiful forms not the longest. The Greeks always made the second a trifle the longest. The other toes gradually shortened and decreased in a rounding line, more and more backwards from the second toe to the small one. The four smaller toes group thus together, while the great toe stands away by itself, leaving a space between it and the second about half the width of the second toe: this gives character, firmness, and delicacy to the foot, but is destroyed in the feet of nations, who wear tight shoes, by the pressing together of all the toes, which thus lose their distinctive character: indeed, in this country it is only children's feet that have not been compressed that afford the elements of beautiful form. The female figure is, on an average, a ninth or tenth shorter than the male. All will have observed that the shoulders are narrower, and the hips broader, in proportion than in the male. These are a few of the proportions adopted by sculptors in regulating their works, and are founded on practical observation. All these measurements are, however, but averages, the adherence to or departure from which is dictated by the character of the figure. Polycletus, in his statue of Doruphorus, or the Lancebearer, was considered by the artists of his time to have so justly hit in its proportions the true medium of beautiful form that it was dignified by the name of the "Rule." This statue is not extant.

6. We have thus briefly considered two of the usual associates of beautiful form—fitness and proportion; we may add to these a few others, such as regularity and variety, simplicity and delicacy, smoothness, gentle gra-

dation, and harmonious combination. Regularity may be noticed as a source of beauty. A circle or square or hexagon has a pleasing element in it. Many elegant flowers are perfectly regular in their plan, so are crystals: the two sides of a face do not please us unless alike. Eyes and limbs should pair. The balance of forces in nature appears to evoke an infinite variety of forms of regularity and recurrence. Geometric forms are the bases of all forms in nature. Even tones of musical sound, communicated to a vibrating plate, will produce in light grains on its surface various pleasing regular arrangements of form. The regularity and recurrence of similar forms of columns in a building produce great grandeur and beauty, and the regular form of the arch and the dome is productive of the same impression. But regularity is not found alone, in those objects which impress us most with beauty of form—it is ever mixed up with a certain graceful variety which modifies a uniformity which would become tedious. Nature, thus working by regular methods and by mathematical process, produces results of the utmost freedom and variety. Hogarth, in his "Analysis of Beauty," published about the year 1753, enumerates as elements of beauty—neatness, variety, uniformity, simplicity, intricacy, and quantity; and he observes that figures, bounded by curved lines, are in general more beautiful than those described by straight lines and angles. Beauty of figure principally depends, in his opinion, upon two lines which he has selected. One of these is a waved line, somewhat in the form of the letter S: this he calls the "line of Beauty." It is found in shells, flowers, and such other ornamental works of Nature, and is also common in the figures designed for the purposes of decoration. The other line, which he calls the "line of Grace," is the former wavy curve twisted round some solid body, as exhibited in twisted pillars and horns, and is the curled form of any spiral. Variety plainly appears, in the instances he mentions, to be so material a principle of beauty that he defines the art of drawing pleasing forms to be the art of varying well; and according to him, the curved line which

is so much the favourite of painters, derives its chief advantage from its ceaseless variation from the stiff regularity of the straight line. The easy curling motion of flame and smoke produces these lines by natural causes, as may be also observed in the rolling of waves, or in a field of corn, when golden billows run before the wind across the field. A certain regularity is observable in the best works of art: the Venus de Medici owes much of her charm to the whole composition of the lines of her limbs and figure being grouped into a somewhat regular form, adding to her other graces a certain symmetry in an architectural and decorative view. This is even still more perceptible in the well-known ancient group of Cupid and Psyche, which has almost the form of an elongated Greek vase: equal as to its sides, small at the top where the two heads are close, it swells out at the centre, and contracts again into a base at the feet. The regularity and succinctness of its form have tended to make it the favourite it has always been.

7. Simplicity is another remarkable quality of beauty. That nation which possessed most strongly and intuitively the perception of the beautiful produced works of a remarkable simplicity of form. The buildings, statues, decorations, and fictile arts of the Greeks were strongly imbued with this unobtrusive yet exquisite quality, conveying to the refined mind a peculiar satisfaction, and producing that impression of unity and elegance which we call classic. The female form, the most charming object in nature, though varied in its outline, is very simple in its character and markings, far more so than the more rugged and powerful structure of man. At the same time this simplicity coexists with the most perfect finish and detail, not only in the female form, but in all the objects of nature and art that strike us as beautiful in form. It consists not in the small number of their parts, but in their unity and subservience to one design.—It is thus united also with the greatest variety. The tree with its many leaves, the meadow with its many flowers, have not probably two exactly alike. No two faces in the whole human

race are probably exactly alike. If beautiful hair and drapery be examined, although the general effect be simple, Nature varies the parts in perpetual change. In the human form there are not two curves, except of double parts, exactly alike; and the swellings and indentation of each individual limb are never exactly opposite. Smoothness also is associated with beautiful form, as it allows of the clear appreciation of the graceful direction of the form, and of the gentle gradation by which the various producing lines slide into each other. Also for itself alone it has claims to beauty, on which Burke especially insists. "Smoothness," he says, "is a quality so essential to beauty that he does not recollect anything beautiful that is not also smooth." Smooth petals and leaves of flowers, a soft and even skin, smooth slopes of ground, unruffled lakes, yield apt examples. In these are exemplified that gentle gradation which is a principal element of Hogarth's two lines of Beauty and Grace. Delicacy enhances other charms, even where it refines them; and fragility, as in the elegant gauze-winged ephemera, Genoese silver-work, &c. All these qualities of beauty must be bound together in harmonious combination, to afford full satisfaction to the refined sense and educated mind.

8. It is not possible, perhaps, to treat fairly the present theme without referring briefly to the question of taste. It needs must that the average of refined and cultivated intellects be taken as the judge of what is beautiful; for the sentiments of beauty have varied much in different ages and nations. The Chinese, for instance, appear to have an idea of beauty very diverse from ours: they appear to dispense wholly with simplicity as a desirable quality, their idea of form being confused to the last degree; and this though their ideas of colour are generally just and beautiful, and the details of their decoration extremely ingenious. Ideas of female beauty in different countries and towns have varied much. Even in ancient Greek and Roman art the foreheads are frequently smaller than those we most admire. In Persia large joined eyebrows are highly esteemed. Beauty of form in China is held to exist

with elongated winking eyes, and to be enhanced by an artificial smallness and deformity of the foot. Some Indians of America compress the seat of intellect, the head, till the forehead assumes the shape of that of an ape. Perhaps it is not more desirable than possible to fix an exact and final standard of taste; but the general feeling and appreciation of the refined and cultivated, of whatever country, will not oscillate far from what may be called the common centre of matured taste. The question is, like all metaphysical subjects, incapable of being pinned down to an exact point; but we may approach sufficiently to an ultimate standard, to satisfy all but an Eutopian.

9. With these brief and inadequate remarks I will relinquish the subject of taste to offer a few more observations, on the degree to which we are able to carry our researches into the laws of beautiful form. I would not appear to treat with too little respect the ingenious speculations of others with respect to certain arithmetical proportions and measurements which they have perceived, or thought they have perceived, in form, which they have considered especially consonant with beauty, and as containing its essence. In speaking of these views in connection with art, I believe that, practically, beauty may be copied, and perhaps in some degree guided, but not originated by such methods. Among the Greeks, who possessed so vivid an intuition as to beautiful forms, I conceive that their highest inventions in art were first seen in nature, or imagined in the mind, or evolved by a combination of both these acts: that they were then drawn out, or modelled, or chiselled, thus being, as it were, created by the mind, eye, and hand:—and that afterwards they were found to possess such and such proportions. It is not because we can work out a certain set of proportions from a beautiful form that we have just grounds for believing that it was arrived at by such means. Indeed, it will be found that theories of proportions by which it has been proposed to build up by calculation beautiful forms, chiefly arise from those who are not remarkable for their power of originating such forms. The foundation of the contours

of many of the Greek and Etruscan vases is that of an egg: there are, however, a great variety of beautiful forms in birds' eggs, not reducible to a common standard. In decoration a certain order of geometric arrangement of parts is not only desirable but essential, as containing the plan, foundation, and setting out for the disposal of the graceful parts which are to complete the work. In architecture, also, this is constantly in action; and in both these departments of art the design of fresh combinations of beautiful forms will go hand in hand with measurement and a certain scale of proportion. But in the human form, beyond the few general measurements from which it cannot much deviate, and yet be just or graceful, new and beautiful forms and characters will not, I conceive, be originated by following any ratio or elaborate theory of lines, but rather by letting the fancy and imagination, restrained however by good sense, play freely around the recollections of nature. All beautiful forms will be found, however, to possess, existing together, flatness and roundness, expressed by the two primary lines of nature, the straight and the curved. In the general oval shape of a beautiful Greek female head there is a combination of roundness and flatness. In the profile a somewhat rounded flatness is seen describing the forehead; a straight line, slightly undulating, continues this down to the end of the nose; a series of compound curves, with little flatnesses, carries this on, downwards, forming the lips, mouth and chin. The neck is a column of circular section, but of which the sides are for some distance nearly straight. The limbs are, in great degree, likewise tapering cylinders, with their sides and surfaces gracefully varying: the principal elements of their longitudinal line being straightness, and of their section a near approach to the circle. In the masculine form there is a larger amount of longitudinal straightness, and the transverse sections of the forms deviate more from the circle, that is, are more elliptical, and possess greater squareness and angularity. The female form has very many curves in its elements of surface. The union of straight and angular forms produces vigour, that of various curves delicacy;

but both these are, in more or less degree, found in common in all beautiful forms.

10. The two primary lines of nature, the straight and the curved, may be called the male and female lines of nature, from whose union arise all forms. In due selection and relation they produce the most graceful and beautiful offspring. In art, refined taste must preside at their marriage. JOHN BELL.

LESSON II.

LIFE OF FLAXMAN.

BY JAMES LEGREW.

1. THE life of a man of genius is never more instructive than when the talents committed to his charge have not

been abused; when his faculties have neither been cramped by the influence of the meaner vices, nor brutalized by sensual indulgence; when, in short, the moral as well as the intellectual man may safely be held up as a model for imitation. Of this there were few more striking instances than the subject of this memoir, John Flaxman. He was the second son of a plaster-figure

maker, and was born on the 6th of July, 1755, in the city of York, which was then the temporary abode of his family. Whilst he was yet an infant, his father removed to London, and kept a shop for the sale of plaster figures. Flaxman was a sickly child, afflicted with spinal disease, and had much of the precocious intellect which frequently accompanies it. He appears very early to have exhibited that observation and love for works of art which distinguished him in after-life; whilst the peculiar nature of his father's business, and the objects with which he was continually surrounded, must have had not a little influence in determining his future pursuits. Unable, from bodily weakness, to mix in the more active sports usual with boys of his age, he was driven to seek amusement from his own resources, and it was, probably, to this apparent misfortune that he was not a little indebted for his subsequent eminence. Seated on a high stuffed chair in his father's shop, he employed himself alternately in reading and drawing. A biographer relates that on the coronation day of George the Third his father was going to see the procession. The child begged earnestly that he would bring one of the medals which were to be thrown to the populace: he was not fortunate enough to get one, but, on his way home, happening to find a plated button, bearing the stamp of a horse and jockey, rather than wholly disappoint his little boy, who was then in a precarious state of health, he ventured, though unwillingly, to deceive him, and gave him the button: the young virtuoso took it, and was thankful, but remarked it was a very odd device for a coronation-medal. He was then five years old. At this age he was fond of examining the seals of every watch he saw, whether belonging to friend or stranger, and kept a bit of soft wax ready to take an impression of any which pleased him. These trivial circumstances are only mentioned to show how early he began the practice of seizing every opportunity of improvement in his art, and of acquiring any knowledge it was right for him to possess: indeed it was a maxim of his, "that we are never too young or too old to become wiser or better." Whilst yet a child he made a great number of models, both of wax and clay,

which are said to have given strong indications of talent.

2. Amongst the persons who visited his father's shop was Mr. Mathew, a clergyman. He had applied to the elder Flaxman to repair a model; and he thus describes his first meeting with the future sculptor. "After having conversed some time, I heard a child cough behind the counter, and, looking over, saw a little boy seated in a small chair, before a large one, upon which he had a book. I asked him what book he had? 'It is a Latin one, sir,' replied the interesting little fellow, raising himself by the assistance of his crutches; 'I am trying to learn Latin.' 'Indeed,' I answered, 'then I will bring you a better book when I come to-morrow.'" From this time Mr. Mathew continued to notice him, and, as he grew up, became one of his first and best friends.

3. When about ten years of age a visible improvement took place in his health; his studies were no longer interrupted by fits of illness, and he modelled and drew assiduously. The taunt of an eminent artist, Mortimer, who, when he showed him a drawing of some human eyes, asked "if they were flounders," although felt at the moment by the sensitive boy, so far, in effect, from discouraging him, redoubled his diligence. When between eleven and twelve years of age he obtained his first prize from the Society of Arts—their silver palette—for a model. At thirteen he received another. The following year he was admitted a student of the Royal Academy, then newly established; and before the close of it, obtained their silver medal. It was about this time that he was introduced to the family of Mr. Mathew, whom he had previously known. His wife was a woman of no ordinary mind and acquirements; the intimate friend of Mrs. Montague, Mrs. Barbauld, Mrs. Chapone, and other highly-gifted women. This acquaintance was of the greatest use to Flaxman, as they kindly opened their house to the youthful aspirant, and here he spent many delightful evenings in refined and intellectual society. His friends not only directed his taste, but encouraged him to study the great authors of Greece and Rome in their own languages. This Flax-

man, to a certain extent, achieved, but never, like Fuseli, to gain a reputation for scholarship.

4. He now received a commission from Mr. Crutchley, of Sunninghill, to make a set of six drawings, in black chalk. The subjects were—Œdipus conducted by his daughter Antigone to the Temple of the Furies. 2. Diomede and Ulysses seizing Dolon as a spy. 3. The lamentation of the Trojans over the body of Hector. 4. Alexander receiving the cup from Philip his physician. 5. Alcestis taking leave of her children to preserve the life of their father. 6. Hercules restoring Alcestis to her husband.

5. During his intimacy with Mr. Mathew's family, Flaxman made some attempts at oil-painting; these, we may suppose, possessed some talent, as one which was afterwards sold at an auction was described in the catalogue as one of Domenichino's. As it was necessary that he should labour for his support, amongst other commissions he accepted one from Mr. Wedgwood, to whose good taste our china manufacturers are so much indebted, to design and model for him. The genius of Flaxman soon imparted elegance even to the commonest articles of earthenware. A set of chessmen, modelled by him, were particularly admired.

6. After having obtained the silver medal of the Royal Academy, he became a candidate for its highest premium, the gold medal, which is awarded for the best original design. In this he was unsuccessful. The competitor to whom the prize was adjudged was Engleheart—a name now unknown. From his own account it appears that he was too sanguine of the issue of the contest, and perhaps careless. He had invited some friends to dine with him on the day of the distribution, and told them to enjoy themselves;—that he merely left them to receive the medal. This disappointment he afterwards alluded to as having been of much service to him in humbling his conceit, and exciting him to increased exertion. It is probable that Flaxman's deficiency in execution might have given the advantage to his antagonist, as at no period of his life did his hand keep pace with his mind. About this time he was employed on a

figure of Alexander the Great, for Mr. Knight, of Portland Place, to whom his friend Mr. Mathew had kindly introduced him.

7. In the year 1782 he married Miss Anne Denman, to whom he had been long attached, and who was well qualified, from her accomplishments and love of art, to assist his studies. On meeting Sir Joshua Reynolds, however, some little time afterwards, in the street, the President said, "So, Flaxman, I am told you are married, if so, you are ruined as an artist; there is no going to Italy now." This speech, it appears, decided his intention of visiting that country, to study the celebrated collections of art there; but his purpose was not carried into effect until five years afterwards. Between his marriage and his departure for Rome he executed, amongst other works, a monument to the poet Collins: he is represented as reading what he told Dr. Johnson was his only book, the Bible, whilst his lyre and poetry lie neglected on the ground. Another to Mrs. Morley, who, with her infant, was lost at sea: she is represented as rising from the waves with her child, and received by angels; and a group of Venus and Cupid for his early friend, Mr. Knight, of Portland Place.

8. In the spring of 1787, having arranged his affairs, he set off for Italy, accompanied by his wife. Here it was his intention to have remained two years; but, at the expiration of that time, his engagements would not permit him to quit Rome, and the two became seven before they were entirely finished. Uninfluenced, on his arrival there, by the vitiated taste which then existed in Italian art, he applied himself diligently to the study of the great masters of Greece and Italy, but more especially the former. The repose and simplicity in the character of their works, and the beauty of their forms, were in perfect accordance with his own ideas of art. Perceiving that the Church of Rome had employed the fine arts as instruments of instruction for her laity, he conceived the idea of effecting the same for the Protestant Church; and hence so many of his works embody subjects either drawn from the sacred Scriptures themselves, or have religious instruction for their end and aim. It was

during his residence in Rome that he produced those series of designs which, more than any other of his works, have immortalized his name. The illustrations of the "Iliad" and "Odyssey" were for Mrs. Hare; the "Tragedies of Æschylus" for the Dowager Countess Spencer; and the "Dante" for Mr. Thomas Hope. They were engraved in outline by Thomas Piroli, and published in Rome in 1793, and subsequently in London. Another work which he executed at this time was a group of four figures, larger than life, for Frederick, Earl of Bristol and Bishop of Derry. The subject was the madness of Athamas, from Ovid's "Metamorphoses." For this the remuneration was so small that the artist was a considerable loser by the work; but Flaxman, without making any complaint, finished the group with the same care and diligence as if he had received an adequate compensation: this work is now at Ickworth House, Suffolk. He also executed a smaller group of Cephalus and Aurora, for Mr. Thomas Hope, which is in his collection. Another subject now occupied his attention, this was the restoration of the celebrated torso, supposed to be a fragment of a figure of Hercules. Flaxman's conception represents the hero sitting, with Omphale standing by his side. That he should not have succeeded cannot be a matter of surprise, as the task was one of such difficulty, that the great Tuscan himself, with his ponderous genius, would most probably have approached it with diffidence.

9. In 1794, Flaxman, with his wife, returned to his native land, hired a house in Buckingham Street, Fitzroy Square, built a studio, and commenced his monument to Lord Mansfield, which is in Westminster Abbey. This commission he had received during his studies at Rome. The Chief Justice is seated on an elevated pedestal, with the figures of Wisdom on one side and Justice on the other. At the back of the monument is a sleeping youth, with an inverted torch, the personification of death. For this work he was more amply remunerated than for the group of Athamas: he received 2500*l.* About the same time he erected a monumental figure of Sir Robert Ladbroke, in Spitalfields church.

10. There are in Westminster Abbey, besides Lord Mansfield's monument, from the chisel of Flaxman, one to Captain James Montague, which represents Victory in the act of crowning him: the flags behind the figure were supplied by the artist at his own expense, as he thought that they would improve the composition:—and a statue of John Kemble. In St. Paul's, a monument to Nelson, in which Britannia points out the Admiral as an example to two young sailors; another to Lord Howe, which represents him with Britannia, History, and Victory; a smaller one to Captain Millar; and a statue of Sir Joshua Reynolds. In Micheldever church, Hants, is perhaps his finest monument, to the family of Sir Francis Baring; in the centre is a sitting figure of Resignation; on each side his celebrated reliefs of "Thy kingdom come," and "Deliver us from evil." Besides these, at Oxford, there are two monuments to Sir William Jones; one at University College, the other in St. Mary's church. At Christchurch, Hants, a monumental group of Lady Fitz-Harris and her three children. A monument to the Yarborough family, at Street Thorpe, near York; another in the same county to the memory of Edward Balme, Esq., which contains the relief of "Instruct the ignorant." In Brighton church, Northampton, a memorial to the Dowager Countess Spencer; a figure of Mrs. Tighe, the authoress of "Psyche," which was sent to Ireland. In Cookham church a monument to Sir Isaac Pocock, which represents his sudden death, in a boat. The good Samaritan, and a monumental bas-relief to the Bosanquet family. A memorial to Mr. Clowes, in St. John's church, Manchester, erected by his parishioners during his lifetime; and in Winchester Cathedral a monument to Dr. Wharton, also by him. The city of Glasgow contains two of his statues in bronze, Mr. Pitt and Sir John Moore; and in the library of the University of Edinburgh there is another of Burns, by his hand.

11. Nor were his works confined to his own country: he executed several for the East Indies. Amongst these were a statue of the Rajah of Tanjore; a figure of Warren Hastings; a monument to Schwartz: two to

Lord Cornwallis. The last of his works for that country was a statue of Lord Hastings. The friezes on the front of Covent Garden Theatre were designed by him, and the figure of Comedy executed by his own hand.

LESSON III.

LIFE OF FLAXMAN—*continued.*

1. In 1797 Flaxman was elected an Associate of the Royal Academy, and in 1800 an Academician. In 1810 he was appointed Professor of Sculpture,—an office then newly created, and which he continued to fill during the rest of his life.

2. In 1820 he suffered one of the severest afflictions which could have befallen him, in the death of his wife, who, for thirty-eight years, had been as it were part of himself; who had shared his early struggles, and witnessed his fame; and although her loss was supplied, as far as it could be, by the presence of his own and his wife's sister, both women of superior mind, he never, perhaps, thoroughly recovered it.

3. It is difficult to enumerate all the works of an artist, whose mind, like that of Flaxman, was continually teeming with new ideas; but amongst the best which he executed, in the last years of his life, was the Shield of Achilles, for Messrs. Rundell and Bridge.—This is of a circular form, and the various figures in relief upon it are intended to represent the universe; the heavens are personified by a central group of Apollo and some of the constellations; the earth by a series of subjects around it, illustrating many of the deeds and employments of men; whilst the sea is indicated by a border of waves which encloses the whole.*—A group of Michael overcoming Satan, for Lord Egremont;—and two small figures of Raphael and Michael Angelo, for Sir Thomas Lawrence. The last work on which he was employed was the designs of all the principal decorations for the exterior of Buckingham Palace, and it was the par-

* Flaxman received 620*l.* for the model and drawings; and one of the casts, in silver-gilt, made from it, was purchased by George the Fourth for himself, and another presented by him to the Duke of York.

ticular wish of George the Fourth that he should execute as many as he could, and direct the rest. This, however, was not permitted: his constitution, always feeble, now showed more decided symptoms of decay.

4. During the last year of his life his studies were occasionally interrupted by illness. On Sunday the 3rd of December, after returning from church, he felt himself suddenly affected with cold, but was sufficiently well to receive some friends at dinner the next day. Inflammation of the lungs, however, succeeded, and all attempts to avert the progress of the disease were ineffectual. He expired on Thursday, the 7th of December, 1826, in the 72nd year of his age. On the 15th of the same month his body was accompanied to the churchyard of St. Giles-in-the-Fields by the President and Council of the Royal Academy.

5. Flaxman was diminutive in stature: his whole appearance was somewhat dwarfish; his head was large, and his knees slightly bent inwards. His forehead was high and expanded, his eyes bright and clear, but the rest of his features a little coarse. The expression of his face when he spoke was highly intellectual, but still retaining a slight shade of that which is peculiar to deformed persons. In his dress he was extremely plain, and wore his shirt-collar turned down over that of his waistcoat. In his social and domestic relations his life was irreproachable. His affection for his wife* ceased only with his existence. His kindness and consideration to his friends, and more especially to his inferiors, exhibit his character in a most amiable point of view. When any of his assistants were in distress, or unable to work from sickness, he made them presents, or sent them their wages, and supplied medical advice, if necessary. To young artists his studio was open, and he was liberal to them,

* Of this a little incident is mentioned by one of his biographers. Unknown to her he caused a book to be made, which he embellished with his own designs and poetry: this he presented to his wife on her birthday. In the first page was the following inscription:—"The anniversary of your birthday alls on me to be grateful for fourteen happy years spent in ur society."

both of time and advice. A promise once made was held inviolate, although the fulfilment of it might be injurious to him. He was totally free from avarice; money he regarded merely as the means of doing good. He was equally without that jealousy of the talents of others, which so frequently dims the characters of otherwise great men.

6. Devoted entirely to art, and finding his greatest happiness in his own domestic circle and the society of a few chosen friends, he mixed little in the great world of fashion. Amongst his more intimate acquaintances who were not artists, were Rogers, Hope, and Hayley. He usually rose at eight o'clock; breakfasted at nine; modelled until one; dined at that hour, frugally; recommenced his studies and read; drank tea at six; and devoted the evening to his family, or to the society of such friends as might casually come in. During the peace of 1802, when Flaxman visited Paris for the purpose of seeing again the works of the old masters, which Buonaparte had placed in the Louvre, he declined to be introduced to the First Consul, whom he regarded as the enemy of his king and country. He also refused to meet the painter David, notwithstanding his admiration of his talents: the humane Englishman shrunk from the atheist who had shared in the atrocities of the first Revolution, and who had been accustomed calmly to sketch the dying agonies of its victims. Nor would he, at any period of his life, associate with persons of loose principles or dissolute character, however brilliant their talents. Although a firm believer in the truths of Christianity, of which the practice of his life gave evidence, and a member of the Church of England, in the communion of which he remained until his death, yet he was, in some degree, a proselyte to the doctrines of Emanuel Swedenborg. The preponderance of the imaginative faculties in his mind, and their continual exercise, may have rendered him more open to delusions of this kind than an ordinary person.

7. As an artist, Flaxman, strictly speaking, must be considered rather as a great designer than a sculptor. The fertility and exuberance of his imagination

scarcely allowed time for his hand to embody the ideas as they poured forth. Added to this there was probably some deficiency in the mechanical faculty. His best works are his outlines; those which required the least time and trouble in their execution. But beautifully as these are conceived, and suggesting, as few outlines do, the roundness of the form contained by them, they are not unfrequently stiff and incorrect.

8. Next to his outlines, he excels, with a few exceptions, in those of his reliefs, which are flat, and most nearly approach drawings. These must be regarded, however, rather as finished sketches than as perfect works of art, but as such exhibit the highest genius. The strongest character and the greatest variety of expression are frequently the result of a few touches; and he expresses, in many instances, a high degree of female grace and loveliness by means of forms which, if examined, are in themselves anything but beautiful, or even correct. In his best works there is something vague; something left to the imagination of the spectator. The more time and labour required in the execution of a work, the greater was Flaxman's failure.

9. In his designs from Homer, Hesiod, and the Greek Tragedians, he appears, with respect to form, character, and drapery, to have adhered to the style of the Greek statues and vases. In the grouping of these outlines we have every variety of the most beautiful and graceful combination, whilst they depict subjects of the most opposite character;—from the strongest and fiercest passions to which human nature is subject—from the fainting despair of Andromache, the deep grief of Achilles, the remorseless calmness of Clytemnestra, and the horror of Orestes, to the most peaceful scenes and employments of rural life, and this with a touching reality. His works are totally free from either affectation, sensual expression, or false sentiment. No artist has given more buoyancy to his flying figures: they seem to float in air. Of this, Mercury conveying Pandora to the Earth is one of the happiest instances. In his designs from Dante he appears to have been somewhat influenced by the style of the great masters of the

middle ages: the profound and gloomy imagination of the mighty Florentine has led his illustrator into unknown regions, and the principle of beauty has in some degree given place to what is intense and extraordinary. Considered as picturesque outlines, in which seeming impossibilities are expressed by a few simple lines, none of his works have, perhaps, exhibited in a greater degree the grasp and versatility of Flaxman's invention; yet it may be questioned whether many of the subjects are not better fitted to the description of the poet than the pencil of the artist. Monstrous and hideous forms, the writhings of agony, and human figures holding their heads in their hands, are scarcely legitimate subjects for art at all, much less for sculpture. Perhaps the frequent introduction of the poet himself with one or other of his companions, produces a kind of monotony in many of these designs.

10. In his sculptural works Flaxman succeeded best where he confined himself to what was purely ideal. When he descended to reality, whether by the introduction of portraits amongst emblematical figures, or in portraiture itself, he almost always failed. His statues of individuals were too matter-of-fact and meagre: he had not Chantrey's power of generalizing subjects of this kind, and giving grace and dignity to the costume of his own age and country. Amongst the best of his bas-reliefs are—the Shield of Achilles, which, with the exception of the forepart of Apollo's horses, may be considered as such, and is one of Flaxman's most skilful pieces of composition. Not only has the artist combined the groups, differing widely in action and sentiment, into one harmonious whole, but, considered as a piece of ornamental art, he has produced a very rich and pleasing effect; the various subjects, which flow as it were in a continued stream round the centre, are united, and yet sufficiently separate to produce no confusion.—The Mercury and Pandora, before mentioned—"Come ye blessed"—and the raising of Jairus's daughter. In the last the calmness of our Saviour, the surprise of the girl and the ecstasy of the mother, are finely delineated. Of his alto-reliefs, the finest are "Thy kingdom come," and

"Deliver us from evil," although in the latter the idea is, in some degree, taken from a group of the "Last Judgment," of Michael Angelo. In this relief the abruptness of the light and shadow, which is admirably managed, materially assists the appearance of struggle.

11. The least successful of all his works are his public monuments. In these not only are the architectural parts frequently clumsy and ungraceful, the figures heavy and ill executed, and commonplace allegory repeated again and again, but in most instances we miss Flaxman's usual skill in composition. Of those which contain groups, Lord Mansfield's is, perhaps, the best. But even here the Judge sits without dignity, while the allegorical figures encroach somewhat too much upon him, and the mace, fasces, and arms, occupy too prominent a place in front; the sleeping youth behind reminds us most of the artist. Captain Montague's monument is a still less favourable specimen of his talents: a figure of Britannia stands in almost a straight line behind the subject of the monument, and her action appears to be rather that of buffeting than crowning. The lions at the base repose naturally, but even these are deficient in detail. In Nelson's monument Britannia again appears pointing out the hero to some young sailor boys. Lord Howe stands amidst a group of Britannia, History, and Victory. The statue of Reynolds is stiff and straight in action, and there is little expression in it of either sentiment or feeling. Kemble is finely conceived; but the repose and thought which it really possesses are considerably impaired by the imperfect proportions, and the dwarfish look of the figure.

12. Many of these defects may be attributed to Flaxman's mode of working. In consequence of his own physical weakness, and his reluctance to employ the assistance of others, his models were usually only half the size in which they were afterwards to be executed in marble. This, no doubt, saved much labour; but he does not seem to have been aware to what extent, by such a process, every little defect was magnified. Of his last figures in the round, the group of Michael overcoming Satan, is the best. With respect to this he

differed from his usual practice, as the model was of the same size as the marble. The composition is bold and fine, and the Archangel, who appears to conquer rather by the power deputed to him than by any exertion of physical force, is finely and poetically imagined: and although there is a degree of stiffness and feebleness in some parts, and the surface represents some harder substance than flesh, yet, on the whole, this is one of the best executed of Flaxman's works. The Pastoral Apollo is much inferior to this, and his figures of Michael Angelo and Raphael, although admirable in point of character, are, like many of his other works, little more than sketches.

13. His lectures are ten in number: the subjects are English Sculpture, Egyptian Sculpture, Grecian Sculpture, Science, Beauty, Composition, Style, Drapery, Ancient Art, and Modern Art. Although as compositions they may be deemed inferior to Reynolds's in power and style, and the expressions are sometimes vague, nor does the word always fit the idea, yet they exhibit considerable research and knowledge, and artists are indebted to him for many useful observations: that on the subject of composition is, perhaps, the best.

14. The qualities which form a perfect artist have never existed in any individual, and genius is rather characterized by its creative power than by the absence of faults; and notwithstanding the deficiency in point of execution, which may be observed in many of the works of Flaxman, there is so much of originality stamped upon them—so great a master was he of composition, so pure and true a delineator of human character and passion—that his reputation as a designer will last as long as good taste and a love for art continue to exist.

JAMES LEGREW.

English Literature.

HISTORY AND PROGRESSIVE DEVELOPMENT OF THE ENGLISH LANGUAGE.

BY GEORGE L. CRAIK.

LESSON I.

BEFORE THE NORMAN CONQUEST.

1. WE shall have upon the whole a just enough conception, as well as a simple and easily-remembered one, of the manner in which the various classes of languages spoken in Europe are distributed, if we say that those of the *Tschudic* stock (or of the Fins and Laplanders) prevail generally in the north,—the *Celtic* (including the Irish and the Welsh) in the west,—those derived from the Latin, often called the *Neo-Latin*, or *Romance* (that is, Roman) tongues (such as the Italian, Spanish, and French) in the south,—the *Slavonic* (of which the principal varieties are the Russian and the Polish) in the east,—and, lastly, what, for want of a better name, we may call the *Gothic* tongues over the whole central region. The chief exception is, that one Tschudic language, the Magyar, is spoken by a population established in Hungary, in the south-east corner of the field of survey. But with that stock of languages English philosophy has less to do than with any of the others that have been enumerated. It is more or less connected with the Latin, with the Slavonic, and with the Celtic tongues; hardly at all with the Tschudic.

2. The stock, however, to which the English language in its original form itself belongs is what we have called the Gothic, or that which may be said to have the central portion of the European continent for its proper domain. Now, without minding the extinct variety known by the name of the *Mœso-Gothic*, which was once spoken by a people seated on the Lower Danube, may regard the existing Gothic languages as forming e great subdivisions, which may be generally

named the *High-Germanic*, the *Low-Germanic*, and the *Scandinavian*. Each of these subordinate groups or clusters of tongues has a certain character of its own, in addition to the common character by which they are all allied among themselves and distinguished from those belonging to quite other stocks. They may be said to present different shades of the same colour. And even in their geographical distribution they lie as it were in so many successive ridges:—the High-Germanic farthest south; next to them, the Low-Germanic, in the middle; and then, farthest north, the Scandinavian. The High-Germanic may be considered to be principally represented by the modern classic German; the Low Germanic, by the language of the people of Holland, or what we call the Dutch; the Scandinavian, by the Swedish, Danish, or Icelandic.

3. And it is farther remarkable that the gradation of character among these three sets of languages corresponds to their geographical position. That is to say, their resemblance is in proportion to their proximity. Thus, the High-Germanic and the Scandinavian groups are both nearer in character, as well as in position, to the Low-Germanic than they are to each other; and the Low-Germanic tongues, lying in the middle, form as it were a sort of link, or bridge, between the other two extreme groups. Climate and the relative elevation of the three regions may have something to do with this. The rough and full-mouthed pronunciation of the High-Germanic tongues, with their broad vowels and guttural combinations, may be the natural product of the bracing mountain air of the south; the clearer and neater articulation of the Low-Germanic ones, that of the milder influences of the plain; the thinner and sharper sounds of the Scandinavian group, that of the more chill and pinching hyperborean atmosphere in which they have grown up and been formed.

4. The name by which our own language is known, and which, so far as appears, it has always borne, the *English* language, means unquestionably the language of the Angles; as *England*, originally *Engla-land*, mean-

the land of the Engles, or Angles. The Angles and Saxons figure in all the old accounts as the two chief bodies or divisions of the invading bands who came over and established themselves in the island of Britain after its abandonment by the Romans, by whom the dominion of thesouthern part of it had been held from about the middle of the first till after the commencement of the fifth century of our era. The Angles and Saxons certainly spoke the same language, with at most only dialectic differences, or such as did not prevent them from being mutually intelligible; they were, therefore, there is every probability, only two divisions of the same people. The natural and ordinary tendency of languages in an early state of society is rather to break up and split into a diversity of forms; no cause, of the nature of which we have any knowledge or experience, could account for the Angles and Saxons speaking the same language if they had not had one language from the first; and that could scarcely have been the case unless they had been all along only different tribes of one and the same people. The probability is that the Angles, or English, was and always had been the national appellation, and that the Saxons were merely a section of the English. The fact, at any rate, is, that, after they had acquired the possession of Britain, they both concurred, Angles and Saxons alike, in calling their common country England, or the land of the Angles, and their common language English, as there can be little doubt it had been called from the time when it first became known as a distinct form of human speech.*

5. This original English was certainly not a *High-*

* The *Saxons* are first mentioned by Ptolemy in the second century. He places them along with the *Angli* in the same district which Tacitus in the first century represents as occupied by the *Angli* and *Chauci*, and Pliny of the same date by the *Ingavones*, of whom he makes the *Chauci* to have been a subordinate division. Suppose the *Chauci* to have been the same with the *Saxons*, and the *Ingavones* with the *Angli*, and we have at once the reason of the *Angles*, or *English*, being the national appellation. It was the general name of the race, or stock, of which the Saxons were only branch. Further: upon this supposition it is not improbable at the name *English* is really the same with *Indian*. We have a root-syllable, apparently, in the names of places and popula-ns, in the various forms of *Ang*, *Ant*, *Eng*, *Ent*, *Ing*, *Int*, *Ind*.

Germanic language. None of the historic notices that we have of the Angles or Saxons place either the one or the other in the south of Germany. Nor is their language, of which, as spoken or written in Britain, we have abundant specimens from the sixth century downwards, marked by the distinguishing characteristics of a High-Germanic dialect. It differs generally from the High-Germanic languages in the same respects as the Dutch and the Flemish (or the native popular speech of Flanders). It would appear, therefore, to belong, with these tongues, to the *Low*-Germanic branch of the Gothic stock of languages.

6. And, among the Low-Germanic languages, it was probably, even before it was brought over to Britain, one of those that inclined most in character towards those of the Scandinavian group. The continental seats of the Angles and Saxons appear to have been mostly to the north of the Elbe, and along the coast of the Baltic. They would therefore be in close neighbourhood or in contact with the countries in which the Scandinavian forms of the Gothic prevailed. And after they came over to Britain their language was exposed there to a new Scandinavian influence. Before the end of the eighth century bodies of Danes, or Northmen as they were also called, began to make plundering descents upon the English coast. Within a century from the date of their first recorded appearance, these Danish invaders had compelled the English king Alfred to consent to their occupation of a large portion of the country; and in little more than another century a Danish dynasty was seated on the throne. It was impossible that the English language, however purely Low-Germanic it may have originally been, should not have received more or less of a Scandinavian tincture from these events. This effect, accordingly, although it may not have shown itself very distinctly in the written language before the Norman Conquest came to put an end to the first form of English literature, became sufficiently apparent when the popular speech after a time rose again out of the ground into which it had been trodden by that catastrophe, and a new native literature began to grow up.

7. But how was it that the extinction of the original Anglo-Saxon literature, which indisputably took place about the time of the Norman Conquest, was actually brought about? Let us endeavour, before we go farther, to obtain a clear and right understanding of how and to what extent the language of the country really was affected by the great political and social revolution under which almost everything else in it that was of native growth was thrown down or changed. It is a question which has been much discussed, and upon which very opposite opinions have been advanced. Formerly it used to be held that the pure English (or Anglo-Saxon, as it has been called by modern philologists) of the times before the Conquest was broken up or destroyed by its having become mixed with the French of the foreigners who after that event acquired the sovereignty of the country: it was imagined that in this way there was produced a new language, which was in fact nothing else than a jumble of the two that had thus met and coalesced. Of late it has been argued, on the contrary, that the two things, the destruction of the old native language of the country and that of its old political and social system, had no connexion whatever, but that the language would have in all probability run exactly the course which it did at this time, and undergone the same fate, if the Norman invasion and conquest had never taken place.

8. The facts of the case are shortly these:—The authentic remains of the Anglo-Saxon of which we are in possession show that, although, of course, like every other language, and, we may say, everything human, everything belonging to this world, it was always changing somewhat, yet its movement had been so gradual as quite to escape ordinary observation from the time it began to be used in literature till we come to the eleventh or twelfth century: it had continued through all that space of four or five centuries to be substantially the same language. But from the date of the Norman nquest, in the middle of the eleventh century, its ory assumes altogether a new character. Hitherto as been like a river, passing, indeed, through a

variety of scenery, and with its waters now perhaps deepening, now expanding, but flowing on all the while with an even current and a smooth surface; after the Conquest it is first as it were dammed up, then dashed over precipices, finally dissipated into stagnant pools or drunk up by the earth. It is a language no longer merely in a state of movement, whether of growth and development or even of decline, but in a state of revolution and complete metamorphosis. In other words, first we have its employment in writing generally discontinued, then universally abandoned; next, we have the knowledge of its structure, and the power of understanding it when correctly written, lost by the body of the people, and only partially preserved in the possession of a few curious scholars or antiquaries; finally, we have it revived for literary purposes in a form so different from that which it had when last so employed that both could not have been popularly intelligible at the same time: it has become, in fact, another language.

9. So much can be clearly established by what we may call documentary evidence. We have nothing written in what can be regarded as true Anglo-Saxon after about the middle of the twelfth century, and scarcely anything else of nearly so late a date except only the concluding portion of the contemporary narrative of public events known as the *Saxon Chronicle*, which breaks off with the termination of the reign of Stephen in 1154; and when the vernacular tongue reappears in literary composition in the next century it has lost nearly all its old grammatical forms, and acquired altogether a new structure and character.

10. Now, it must be admitted, to begin with, that this new English, however it may have arisen, presents no appearance of having had anything of a French parentage. There is no trace of the French language to be detected in it. It has borrowed no words, or next to none, from that source, nor have any of its grammatical innovations a French character. It clearly, therefore, is not the product of the intermixture of the foreign tongue brought over by the Normans with the old language of the country, or of any kind of direct

action of the former upon the latter; and so much of what used to be the accepted account of its origin must be allowed to be untenable and unfounded.

11. The new English is manifestly in the main nothing else than the English, or Anglo-Saxon, of the time before the Conquest divested of the greater part of its proper grammar. It is not a mixture of the old native tongue with the French, or with any other; that did not come till a later date; the new language was at first only the old one transformed. It was not English changed into another language by having become half French; such a conversion was not undergone by it till a subsequent stage of its history; as yet it might be rather said to be only the old language curtailed or simplified by having lost or thrown off what once made part of it.

12. But it does not follow, on the other hand, that even with such a transformation as this the Norman Conquest may not have had something to do. Although that great political and social revolution did not in the first instance break up or corrupt the ancient language of England by letting in upon it an inundation of French, as used to be asserted or assumed, the corruption, which was indisputably contemporaneous with the Conquest, or rather immediately followed upon it in the order of time, may yet still have been its consequence as well as its sequence, the operating cause in some other way.

13. It has been said that all the languages of the same stock or branch to which the English belongs have undergone more or less of a similar transformation. The German and the Dutch, the Swedish and the Danish, had all formerly, we are told, a richer or more complicated grammar than they now possess. Hence it is inferred that a simplification of their grammatical structure is a change which it is natural for all languages of this class some time or other to undergo. And therefore, it is argued, it was sure to have befallen the English just as it did, although the Normans, by whom the country was invaded and taken possession of in the eleventh century, had never left their native soil.

14. But this reasoning, at the same time that it takes more for granted than it would probably be easy or possible to prove, disregards some of the most important facts of the case. We do not know that the change asserted to have taken place generally in the Germanic and Scandinavian tongues was brought about in any of them in such circumstances as would make the case a parallel one to that of the English. In fact we do not know in what circumstances it may have been brought about. It is by no means certain that it may not have been in every instance the effect of a crisis in the social condition of the people speaking the language of the same kind with that occasioned in England by the Norman invasion. That any language, no matter of what stock, which has been long completely subdued to the service of literature, as was the case with the Anglo-Saxon, should within a brief space experience such a transformation except under the shock of some national convulsion or other external violence, is in truth nearly inconceivable. No such thing has happened in the case of any language of which we can be said really to know the history. On the contrary, in every such case the language has remained entire and substantially the same so long as the social system of which it was what we may call the established exponent, or, as we might say, natural voice, has been permitted to exist, and has been disintegrated or broken up only when that too was overthrown.

15. Take, for example, the Latin or the Greek. Both continued to be written, and no doubt also to be spoken, by the educated classes, with precisely the same grammatical structure that they had always had, the former till the last days of the Western Empire, the latter till those of the Eastern. But, with the extinction of the system of social organization with which it was connected, each language,—the Latin after a literary existence of eight or nine centuries, the Greek after having been employed in composition without any variation of its grammatical forms for nearly three times as long,—became what we call dead, that is to say ceased to be generally written or spoken or understood, and

gave place, wherever it had been so in use, to what was to all intents and purposes a different speech. Latin became, in Italy, Spain, and Gaul, first Romance, and eventually what we call Italian, Spanish, and French; in the Eastern empire Greek became Romaic; and, notwithstanding whatever of connexion, near or remote, may have existed in any case between the new popular tongue and the old classic one, to those who grew up speaking the former the latter was unintelligible.

16. Have we not an exact parallel to the case of these two languages in that of the Anglo-Saxon? This too retained its original structure so long as the peculiar national civilization with which it had grown up continued to flourish, and assumed a new form, or rather fell into a state of dissolution and ruin, out of which if it ever was to re-arise it was to be as another language, when that civilization was broken up and superseded. It was therefore, in fact, after all by the Norman Conquest that the regular old Anglo-Saxon language was brought to an end, and converted into the different and more simple popular speech which took its place, as the philology of the last generation used to hold, though not in the way or through the instrumentality which that theory supposed, namely, through being brought into contact with the corrupting influences of the foreign language imported by the invaders. There was certainly no such intermixture till a considerable time after the new English had fairly taken root, and completely supplanted the old as the general and proper language of the country; no trace of anything of the kind is to be detected in the earliest specimens that we have of that new language (new at least in literary composition); its peculiarities would none of them be accounted for by the supposition in question; and they are all easily to be accounted for and explained in quite another way.

17. The English of the twelfth and thirteenth centuries is merely the English of the ninth and tenth centuries in ruins, or in tatters. It is the written language, of course, that is referred to in both cases; of the spoken language we know nothing; that may have been the same at both periods; the comparatively uninflected English

which appears for the first time in written composition in the eleventh century may have been long before, or may have been always, the ordinary English of the uneducated classes. What alone is certainly new is its substitution in writing at the date that has been mentioned for the other English of a more complex grammatical structure, in which everything that has come down to us from earlier ages is written. The fact that has to be accounted for, is that of the dying out of the original form of the language. What was it that made the old Anglo-Saxon cease to be written? Undoubtedly its having ceased to be read and understood. And that, again, can only have been brought about by the dissolution of the system of civilization of which the understanding and reading of the old literary Anglo-Saxon was what we may call part and parcel. It is impossible to conceive of such an effect being otherwise produced.

18. Languages do not die of mere old age. Let the social condition in which a particular language is the established organ of expression, the literary organ as well as the ordinary instrument of communication, continue to hold together, and the language will not perish. The older it is, the longer it has been in use, the greater is likely to be its tenacity of life. But a literary language demands, as the condition of its existence, an educated public to which to address itself. This condition was wanting for the old language in England after the complete occupation of the country by the Normans. It may be, indeed, that the decay and destruction of the Anglo-Saxon social system are not to be exclusively laid to the door of the Norman Conquest. It must have been giving way for nearly a century before that event, or ever since the death of King Edgar in the year 975, from which date the country had passed first through the long reign of Ethelred the Unready, which was a succession of national calamities and disgraces from beginning to end, and then through a quarter of a century of a preliminary foreign domination, that of the Danes, followed by nothing better than the factious and turbu-

lent space of about the same length forming the reign of the Confessor, who, besides his feebleness of character, was, notwithstanding his birth and descent, by habit and tastes and connexion scarcely less a foreigner than his Danish predecessors. All this must have gone far to destroy the life and spirit of the old English nationality long before the coming of William and his Normans was apprehended or dreamt of. In fact, Anglo-Saxon literature may be said to have been all but extinct for a century before the Norman Conquest. But that catastrophe gave it the finishing stroke, and made its revival for ever impossible.

LESSON II.

After the Norman Conquest.

1. The written English of the age immediately subsequent to the Conquest has been described as displaying "all the appearance of a language thrown into confusion by the circumstances of those who spoke it;"* and in reply to that representation it has been asked if men, in troubled times, "are prone to forget the natural means of communicating their ideas, to falter in their speech, and recur to the babble of their infancy."† But this is not what is supposed, or what it is at all necessary to suppose. The English people of the twelfth and thirteenth centuries spoke the language of their forefathers incorrectly, in consequence merely of not being trained and instructed in the right way of speaking it. They grew up, owing to the unfortunate circumstances in which they were placed, without that education, and those habits of reading and writing their native tongue, which preceding generations had enjoyed and been formed by. No doubt there had been in all times much incorrect speaking in the lower grades of the population; but till now more or less of culture had always been maintained, not only among the higher ranks but generally throughout the middle classes, or what we may call the body of the nation.

* Mitford's 'Harmony of Language.'
† Price, in Preface to Warton's 'History of English Poetry.'

2. It was much as it is among ourselves at the present day. Books, no doubt, were scarce, and of mere reading and writing there was a great deal less than there now is; but purity of speech may be kept up with very little of that. All that is necessary is, that to speak correctly should be recognised as one of the evidences or customary marks of a certain social standing. At the present day, in every civilized country, of the persons by whom the language is spoken for the most part grammatically and properly by far the greater number never open a book. They only copy after, or follow the fashion set by, the comparatively few who write and read. They adhere to a certain manner of speaking their native tongue, as they do to a certain description of clothing by which they are equally distinguished from the working classes and assimilated to the classes above them. The nature of both of these two things, the mode of speaking and the mode of dressing, is such that the highest style of either admits of being easily imitated by many persons who stand very far below the highest point in wealth or in culture. The coat of the shopkeeper may not be of so fine a cloth as that of the nobleman; but still it may be said to be undistinguishable from that in comparison with the entire dissimilitude that separates it from the fustian jacket of the labourer. So likewise with the speech of the middle classes. It is not all through the portion of the community commonly so denominated, or nearly all through it, a speech actually acquired in grammar-schools and kept up by converse with books; but yet it is substantially or in the main the same with the speech of persons of education and reading. It is an imitation, and on the whole a successful imitation, of that.

3. But all this would pass away, this generally correct mode of speaking would soon be heard no more in the land, if the class of scholars and readers, the class possessing wealth and leisure, were to be extinguished. Now, that is what happened to the native population of England on the conquest of the country by the Normans. No higher class, scarcely any middle class, was left of their race or speech. They were not put to death, or

driven out of the kingdom; but they were removed from the position which they and their ancestors had been wont to occupy, thrown down from the summit or the upper regions of the social edifice to its basement, or its cellarage underground. They who had been lords and masters were reduced to be servants and slaves. The class for whom English books had heretofore been written, or scholarly English verse composed, no longer existed. Such books and such verse, accordingly, were no longer produced. The fountain was sealed from which the national speech had used to flow out in its purity over so large a portion of the population; the "well of English undefiled" was dried up. There remained only so much of the old language as, being absolutely necessary for the purposes of ordinary communication, was indestructible and incapable of being lost until another language should come to take its place.

4. For some kind of language every community of men must have. Here at least it is true that nature abhors and will not tolerate a vacuum. One language can never be wholly expelled from a country except by the intrusion of another. Man and language are as it were opposite poles of the same axis. Wherever you have the one, you have the other. Not only has man nowhere been found without a language; language is the possession of man alone. And in favourable circumstances, even much more of a language than is sufficient for the necessities of human existence may be preserved for a long time without a literature. But the employment of a language for the purposes of literature always implies or leads to an artificial elaboration of it to a certain extent, and whatever of its structure may have resulted from that process may be expected usually to moulder away when it continues to be used for other purposes after its literary cultivation has ceased. The circumstances in which the English language was placed after the Norman Conquest were the very reverse of favourable for the preservation even of what of it was most purely natural; and even of that undoubtedly much now decayed and dropt off

which, in a happier condition of things, the lips of men, without any aid from letters, might have kept alive and vigorous.

5. The Norman Conquest, however, although it prostrated for a time both the English people and the English tongue, did not destroy or exterminate either. Trodden down as they were, both still not only lived, but continued to cover and fill the land, and were destined yet to rise up again and rule it. And, apparently, both were eventually regenerated and restored to their old supremacy in the same way, namely, by the absorption and assimilation of the intrusive power by which they had been at first overthrown and subdued. Everything in modern England, indeed, may be said to be a mixture of English proper, or what is commonly called Anglo-Saxon, with Norman or French; the people, the language, the laws and government, and the entire social system.

6. When they first met, however, the two ingredients which have thus combined were everywhere hostile and divided. And even now, although they have to so great an extent become mixed together, they are very variously associated in different cases. In some a considerable amount of antagonism still subsists between them; nor is their mutual aversion or repulsion in such circumstances always by any means perfectly quiescent. Bound together as they are, they yet struggle to release themselves or to conquer each other. In other things, again, where they are in sufficient accordance, they are still rather joined or attached than fused into one, and while, it may be, the body or substance is English, the superficial or decorative part is Norman. Finally, where the combination is most complete, the two ingredients enter into the common product in very various proportions. Generally, however, the basis of the compound is English.

7. This is especially the case with regard to both the people and the language. The more sluggish Saxon blood has been only enlivened by a few drops from the fiercer Norman; and, in the same manner, it is only as it were the gilding of the language that is Norman or

French. In some respects, indeed, the two cases are not analogous. The mixture of the two languages, the French and the original English, was the combination of a Latin element with a Teutonic basis; that of the two races was the combination with a Teutonic basis of a Scandinavian element. The French which the Normans, or Northmen, brought with them to England was a speech only recently adopted by them, since they had acquired a settlement in France. They were not themselves French, like their present language, but Scandinavian or Danish. The two bloods which were mixed, were therefore more nearly related than the two languages; for the Scandinavian and the Teutonic populations are subdivisions of the same branch, whereas the Teutonic languages belong to one branch of the great Indo-European stock, and the Classic, including Neo-Latin, of which the French is one, to another.

8. Moreover, the manner in which the foreign element has affected the population is considerably different from that in which it has coloured, or otherwise transformed the language. The Norman blood has not penetrated beyond a very limited depth; its influence upon the mass of the nation, has been rather in the way of radiation or reflexion than by actual interfusion. French has mingled and combined with our native Gothic speech throughout its entire extent, though more plentifully with some departments of it than with others. The mixture would thus appear to have been the most intimate and complete, in that one of the two cases, in which the previous relationship was the most distant. Nevertheless, the mixture of the races, and the mixture of the languages, resembled and accorded closely in respect both of the relative quantities in which the native and foreign elements were present in each case, and also of the time and circumstances of their coming together.

9. The two combinations, that of the races and that of the languages, indeed, seem to have taken place simul-
ously, or rather to have followed one another in
diate succession as cause and effect. It was in all
bility, the mixture of the races that brought

about the mixture of the languages. This is the natural supposition; and it is in sufficient accordance with all the facts and indications of which we are in possession.

10. For at least a century after the Conquest the two races appear to have kept quite apart. It has been generally held that it was not till after the accession of Henry the Second, in 1154, that any movement towards a coalescence between them began to be made. Down to this date the Normans were still looked upon as foreigners and enemies. Their only intercourse with the general population of English descent was probably not much greater than what goes on in countries where negro slavery prevails between the few proprietors of the soil and the swarm of its cultivators of another colour. Perhaps the English still generally cherished the hope of expelling their invaders and spoilers, till Henry Plantagenet, with the blood of Alfred in his veins, came, in the fading light of their patriotic dream, to reconcile them to the yoke with the illusion that they had got back the line of their ancient kings.

11. We may allow about another century, or from the commencement of the reign of Henry the Second to the close of that of his grandson, Henry the Third, in 1272, for the old alienation to wear generally out. One century of four Norman kings—the Conqueror, Rufus, the first Henry, and Stephen—during which there was not even a tendency towards association between the two races, will thus have been followed by another, covered by the reigns of the first four Plantagenets—Henry the Second, Richard the First, John, and Henry the Third (a father, his two sons, and another, exactly as before)—in which this mutual aversion gradually thaws and evaporates. After this, or from about the middle of the thirteenth century, the process of amalgamation may be regarded as going rapidly on. We may suppose it to have been completed in about another century, comprising the reigns of the first three Edwards, which terminated in 1377, or, we may say in round numbers, about three hundred years after the Conquest.

12. Now, in so far as the evidence of the literary remains that have come down to us from these three centuries enables us to judge, the commencement and progress of the conversion of the vernacular language from a purely Gothic or Teutonic form of speech into a compound of Teutonic and French exactly correspond with what we have just found to be the history of the gradual approach and at last intermixture of the two races. For the first two-thirds of the space in question the English tongue appears to have received scarcely any French. We have an ample specimen of the English of this date in the work called the *Brut* of Layamon (perhaps the same with the modern *Lawman*), a metrical chronicle of British history extending to not much short of thirty thousand lines. Two versions of it have been preserved, the earlier of which is probably to be assigned to the close of the twelfth century, the more recent perhaps to about the middle of the thirteenth. Both have now been printed in full, most carefully and in all respects admirably edited by Sir Frederick Madden; and he states that in both together he has not found in all quite a hundred words of French derivation. There are about fifty in the one version and about eighty in the other, about thirty being common to both.

13. Even in the Chronicle of Robert of Gloucester, which belongs to the end of the thirteenth century, the words of French origin are still very few in number. But by this date, in the commencement of the age of the Edwards, the language as commonly spoken was probably already beginning to be visibly coloured by the new element that was acting upon it and in it, however much some less courtly writers, such as the author of the *Visions of Piers Plowman*, may have as far as they could stood out against the reigning fashion of expression, and endeavoured to keep to, or to go back to, the pure and simple English of other days. For a time there were probably two opposing sects or schools of writers in the national language; for such, at any rate, English was now fast becoming, or had already putably become, whether it was to preserve a pery homogeneous character or no. But at last all

acquiesced in what was manifestly the destined course of the language, and the revolution which it was inevitably to undergo or rather had already undergone. By the middle of the fourteenth century, or we may almost say from the commencement of the reign of Edward the Third (in 1327), it had lost all chance of escaping from being to a considerable extent gallicised, or permanently variegated by an intermixture of French. It had as it were contracted a marriage with that foreign tongue, or combined with it in a union which was to be indissoluble; the two had become one.

LESSON III.

French Element.

1. This is by far the greatest revolution and in every way the most important event in the history of our national speech, at least since the Norman Conquest: in some respects it is more remarkable even than the destruction of the original inflectional system of the language; it is, at any rate, a transformation of altogether a different character from that. It is at the same time, like that, a passage in the history of the language the common accounts of which involve a good deal of loose thinking and unfounded statement.

2. First, with regard to the way in which it was brought about. It has been usual, especially with those writers who are most disposed to regret what they call the depravation or corruption of our original English by its becoming mixed with French, to denounce the great father of our poetry—and, indeed, we may say, of our literature—Chaucer, as the chief or sole author of the mischief. But nothing can be more certain than that Chaucer—like every other poet in every age, country, and tongue—must have employed merely the ordinary current language of his day. This was an absolute necessity of his art. He could not otherwise have written at all. The notion of any writer in any circumstances inventing a language for himself, involves an entire misconception of the nature of language.

would not be more absurd to suppose him to have invented the air he breathed. Languages are not invented, and not to be invented; you might as well talk of inventing or fabricating a field of growing corn or a waving forest; a language is a spontaneous production; it is not made, but grows. It is never the creation of an individual, but always the expression only of the mind and sentiment of a community. The individual must take it in the main as he finds it, just as he must take the air of the country as he finds it; all that he can do to modify the natural production in either case is merely to manage it skilfully. The imagination that Chaucer could have done anything really to alter the substance of his native tongue is as extravagant as it would be to assume that a great chemist might alter the constitution of the atmosphere in the part of the world in which he resided.

3. If this general consideration wanted any support, it would be found in every known fact connected with the case. The increasing absorption of French is a characteristic of all the written English that has come down to us from at least a whole century previous to the appearance of Chaucer. His English has more of it than that of Robert of Gloucester and that of Robert de Brunne, merely because he belongs to the end of the fourteenth century instead of to the beginning or the middle of it. If he uses many words of French derivation, so do his contemporaries, Mandevil, Wiclif, Trevisa, and others. Such partially gallicised English was manifestly the common English of the time.

4. But what is still stronger than all this is the evidence of the tendency of the language, and of the course it was taking, with which Chaucer's own vocabulary supplies us. A considerable number of the words which we find in his writings have since fallen into desuetude; but whether is it those of French extraction or those of pure English stock that have in the largest proportion thus died out and disappeared? Those of the latter class decidedly. Of every three Chaucerian vocables that have become obsolete, probably two on an average are Saxon, or old English, and only

one French. This shows to demonstration what the tendency of the language had come to be. If most of Chaucer's French words were, as is alleged, of his own invention, or never employed by any previous English writer, that only makes our argument the stronger. Notwithstanding this disadvantage, these new words of foreign origin clung to the language upon the whole with greater tenacity than a corresponding number of those which had always belonged to it. There was, in any case, a portion of its old Saxon which it was more ready to shake off than it was its acquired French. The latter annexation, at least up to the point to which it had been carried at the time when Chaucer wrote, has proved upon the whole more adhesive than what was originally of the same substance with the rest of the language. The cement has proved stronger than the natural bond of connection. The graft has evinced more life and vigour than the branch which was of the same wood with the tree.

5. Nor is this all. The language continued to throw off Saxon and to adopt French in its stead for a long time after the age of Chaucer. The process went on at an accelerating rate at least down to the end of the fifteenth century. It was not till then that the absorption even began to abate something of its energy. Nor had the point of saturation yet been reached: the adoption of new words from the French, or, which is the same thing, from the Latin, has never altogether ceased to the present hour, and is still what we may call a constitutional habit of the language.

6. For the most remarkable fact of all remains to be stated. Ever since this habit began to operate, and it came to be the practice of our language to borrow such new words as it had occasion for from the French, it has entirely given up drawing upon its own proper Teutonic source. Probably not a single word of Anglo-Saxon extraction has been added to our vocabulary since the Norman Conquest; when we want a new word it is never from the Anglo-Saxon that we form it. Even when we do not go to the French o

the Latin, we never go back to that. But this is not all. There is probably no instance of a Saxon term which had dropt out of the language having been restored to it in all this length of time. That, indeed, is only in conformity with what appears to be a universal law of human speech. When a word has once fairly expired, it would seem that it can no more be raised to life again than can one of ourselves. If the master of style may sometimes, according to Pope's famous exhortation, "command old words that long have *slept* to wake," that is the utmost that is possible. If the word be really dead, it cannot be revived. For what is it that the dying out or extinction of a word implies? What is it that alone can bring about such a catastrophe? A particular word may come to be less frequently used than it had been wont to be; it may go out of fashion and be generally neglected for a time; such quiescence is what has befallen many of those which Pope refers to—"words which wise Bacon or brave Raleigh spake;" but such words are not dead. A word dies only when something in its form or constitution, something that is an essential part of it, encounters a state of the language generally with which it cannot consist or accord.

7. For example:—Formerly the favourite or most prevalent English prefix was the syllable *ge*; there are some thousands of Anglo-Saxon words of which that is the commencing syllable; it is prefixed not only, as in modern German, to the past participle passive, but to almost every other part of the verb. There is not so much as a single instance of it remaining in our existing English. Even its more recent representative *y* has entirely disappeared from the language, except only in one or two forms, such as *yclad* and *yclept*, which are still sometimes employed in a burlesque sense. For the most part the little antique appendage has simply dropped or been twisted off: in some cases it probably still retains its place, having escaped destruction by disguising itself in the form of some other initial syllable not under the same ban. Neither in its original shape of *ge*, nor even as abridged and softened into *y*, could it now live in the language, any more than the light of a

candle, or the light of life itself, could subsist in an atmosphere in which there was no oxygen.

8. Words and forms of words die out from a language somewhat as certain diseases which may once have prevailed in a country die out, or rather as plants will sometimes prove to be no longer capable of cultivation in a soil in which they have for ages been accustomed to flourish. We may not be able to detect what is the precise nature of the change that has taken place in the circumstances upon which their hold of the language depends; but death here, as in every other case, can only be the consequence of the cessation of some condition essential to life. The language has assumed a new character with which the particular verbal form, or class of forms, is incompatible. No wonder, then, that for a word once dead and buried there can be no resurrection; for that would demand that the entire system of the language should be rolled up again into a state or shape which it has passed through and outgrown.

9. It may be that our Saxon words are not now dying out faster from the language than those which it has borrowed from the French or the Latin; although that would certainly be a supposition far too favourable to the former for the whole extent of the period that has elapsed since Chaucer wrote; for of the words found in his poetry that have now become obsolete, those of Saxon origin, as has been explained, make by much the larger proportion. But even thus the Saxon part of the language as it existed in the age of Chaucer must have undergone a great diminution as compared with what of it is of French or Latin extraction. What happens in the case of the latter is merely that, when a word drops out and disappears, another of the same French or Latin parentage always takes its place; the individual words may be changed, but the new ones are still as much French or Latin as the old ones were. Not only so: those that supply the place of such of the Saxon ones as have died out have been also obtained from the same quarter. Generally speaking, the only accessions that the language has received in recent

times have been drawn from that source. None of them, at any rate, have come from the old Saxon. Not a single new formation from the Saxon has been added to the language since it first formed its union with the French. Ever since then the soil from which it originally grew and was fed has ceased to yield it any further sustenance. It has, as it were, wedded the French, and thereby subjected itself to the natural law of becoming detached from its parent and dependent henceforth upon its husband for everything.

10. If the process were to go on indefinitely, it is evident that the Saxon part of our vocabulary might at last be in this way altogether exhausted and supplanted. But of course it would take a very great length of time to effect such a revolution as that. In the condition to which the language has now attained, what wearing out of old words may still be taking place is extremely slow. Probably not more than two or three are lost in a generation. It was very different, however, in an earlier era. The proper period of the mingling of the two languages may probably be defined as extending from about the middle of the thirteenth century to the middle of the sixteenth; but the displacement of the old by the new appears to have been more especially active throughout the fourteenth and fifteenth, or from about the year 1300 to the year 1500. The fermentation which was to subside into their perfect union seems to have continued with little diminution down to the latter date. Then the absorption of French gradually became more and more languid, till at length it ceased altogether, except only in so far as it served, under what had now become the law or established habit of the language, to supply the very slight waste which may be called the natural decay of its original vocabulary.

LESSON IV.

RELATIVE STRENGTH OF THE TWO ELEMENTS.

1. The statement that is commonly made is, that, notwithstanding the quantity of French which has now established itself in the language, its pure Saxon words

are still much more numerous than those of French or Latin derivation. Sometimes we are told that three-fourths of our modern English, sometimes that four-fifths, are still Saxon. Most certainly, if it be the entire vocabulary of the language that is spoken of, such estimates are altogether erroneous. Any person may soon satisfy himself by examining a few pages of an English dictionary, at any part of the alphabet at which it may chance to open, that the Saxon words are everywhere far outnumbered by those imported from the French or the Latin.

2. We should probably not be very far wrong in assuming that, of the words catalogued in our dictionaries, for one that is Saxon, three or four are not. If, putting aside such words as have come to us from other sources, which are principally a small number from the Celtic dialects, and a large and continually increasing crowd of scientific terms formed from the Greek (the only considerable word-manufacture which still goes on in the language), we take those of Gothic and those of French or Latin extraction to amount together to about 50,000, the former can hardly be reckoned at more than from 10,000 to 15,000 against from 35,000 to 40,000 of the latter. And whatever movement may be still taking place, is tending, as has been shown, still farther to enhance the disproportion between them; for, while we still occasionally adopt new formations from the French or Latin, we never do so from the Saxon. When a Saxon word disappears from the language, if its place be supplied at all, it is never by another of Saxon or Gothic etymology.

3. But although such may be the case with regard to the 50,000 words of the dictionaries, it is very much otherwise with the 10,000 employed in ordinary writing, and still more so with the 5,000 or thereby which suffice for common discourse, or form what may be called our oral or colloquial English. Probably of the 10,000 about one-half, of the 5,000 about three-fourths, may be Saxon.

4. This explains how it happens that the common

assertion of the preponderance of Saxon in the language may seem to be borne out by the evidence of certain literary compositions which are sometimes appealed to. The more simple and natural the style, the greater will be the proportion of Saxon words. In the Lord's Prayer, for example, almost all the words are Saxon; only three or four (*temptation*, *deliver*, *power*, *glory*), are of another stock. All our most expressive and poetical words, also, are Saxon; it is such alone that present distinct images to the mind, and therefore that are capable of denoting anything sensuously, or in any degree in the manner or with the effect of a picture; generally, when an object of thought is called by a Saxon name, it appears to us as if we saw it with our eyes. This, which must have been still more the case when the language was homogeneous, and the signification of most of its elementary terms was made manifest and universally familiar by their continual recurrence, under every variety of combination, in the performance of the same function, is due to our Saxon words being, as it were, the actual growth, and as such we might almost say substance of the national mind. We know them from the beginning. Our French and Latin derivatives are imports from abroad, the produce of another soil, which come to us only in the fruit or the grain, and of which we know nothing in the blade or the bud except it may be by description.

5. This circumstance, too, of the Saxon part of our vocabulary being the most living, or the only really living, part of it, may diminish our surprise at the remarkable fact that, notwithstanding so much of the language being of foreign derivation, its grammar should still be throughout purely English or Saxon. Something of its original inflexional system is lost, but what remains is all of the original character and substance. It has not been in any degree Gallicised or Romanised here. The French and Latin words which have become incorporated with it have all gathered round the old skeleton which it had before the intermixture began. The structural nature of the language has been the same since its birth. The foreign accretion has been

assimilated to that to which it has joined itself. The whole consists mainly, in its present state, of two great elements, and the non-Saxon one may be in the largest quantity; but yet the basis of the compound is clearly and indisputably Saxon.

6. On the other hand, however, what may be called the musical character of our existing English, if it cannot be held to be entirely the product of the non-Saxon element of the language, has at least been thereby materially controlled and modified. This is a most important fact. Music, taken in the largest sense, is to the ear what colour is to the eye; each is really the only thing that the organ perceives. In no case do we actually see anything but colour; whatever else we seem to see is only an inference from that. Our conclusions as to the outline, figure, position, and distance of the objects which we look at are merely, in so far as they depend upon the information of the eye at all, judgments which the mind builds upon what that organ discerns of colour and shades and other distinctions of colour. In the same manner all the difference which the ear perceives between any one word and any other may be said to be only a difference of music. More especially, or in a more limited and distinctive sense of the term music, such is the sole and whole difference between any two forms or dialectic varieties of the same word.

7. What has principally given rise to dialects may be said to have been difference of musical taste or impulse. The same word is commonly spoken with a rising inflexion in one part of the country, with a falling inflexion in another,—here with the accent at the beginning, there with it at the end,—by one set of people with a strong guttural enunciation, by another labially, or dentally, or "trippingly on the tongue;" such fashions once set propagate themselves as if by a sort of infection or contagion, till each becomes all but universal within a certain sphere, or is imbibed, as if it lived in the air, by every individual born and brought up in the district, becoming with each a habit, a second

nature, a part as it were of his personality. And from the comparatively slight differences thus originated, with the tendency inherent in every kind of divergence to become always wider and wider, any other differences may in course of time arise. If all languages have really sprung from one original language, this diversity of musical taste, organization, or capacity, must have been the main primitive cause of the multiplied forms which human speech has assumed.

8. Or, let us take what is less of a mere supposition; let it be the case of any two languages which are manifestly both, for the greater part, only different forms of the same older language, the Italian and the French, for example, which are both substantially but transformations of the Latin. If we could fully detect the musical law or tendency that governed the growth or formation of each of these two tongues, we should probably be able, from that alone, to explain and account for most of the characteristics in which the one differs from the other. What else can it have been but the differing musical tendencies by which they were severally guided and moulded that made the Latin *ubi* (where) become *ove* in Italian, and *où* in French, or the Latin *natio* (nation) become *nation* in French and *nazione* in Italian, and pervaded the two languages with whole systems of other forms in accordance with these,—so full and flowing usually in the one, so compressed, flattened, and curtailed in the other? Whatever other influences may have combined to operate such effects, the musical influence has undoubtedly been the ruling one and that which has marshalled and principally directed all the rest.

9. The extent to which the original musical character of the English language has probably been affected by the foreign element that has become incorporated with its original Gothic substance or basis, would, it will therefore be understood, be a very interesting subject of investigation. The general effect, undoubtedly, has been greatly to reduce the roughness and unwieldiness of the earlier form of the language. The Anglo-Saxon, unmixed English of the period before the Conquest,

encumbered as it is with gutturals and ponderous consonantal combinations of all kinds, cannot have been a very mellifluous form of speech; the equally unmixed but broken-down English of the first two centuries after the Conquest, commonly known as semi-Saxon, was probably only somewhat more easily pronounceable as being suited to a mode of pronunciation more irregular and slovenly. At all events, if these older forms of the language had any musical beauty to boast of, it was of a character altogether different from that to which the national ear has since become accustomed.

10. It will hardly be contended by any one, that our modern English is too soft or mellifluous; it cannot be said to have had anything of effeminacy of character imparted to it by the modification which its musical structure has undergone under the influence of the French. But, while it still remains a sufficiently manly language, with surely no want of consonantal combinations or any other constituent of bone and muscle, the change which has been operated in its musical system has at least had the effect of bringing it more into harmony both with the other most extensively prevalent living tongues of Europe, and also with the two ancient tongues which are the great fountains of the literary civilization of the modern world. Our English euphonic laws and forms, although not throughout identical with, are no longer at war with those of the Greek and the Latin, the Italian, the French, and the Spanish. Every language has, of course, some such laws and forms peculiar to itself; but yet these other languages and our own may all now be said to be musically constituted, for the greater part, upon the same principles. Even what is peculiar in each, though it may sometimes be strange to the others, is scarcely ever absolutely revolting.

11. Among the riddances for which we are indebted to the French—in this particular founded upon and perfectly accordant with its parent Latin—is especially to be noted that of the aspiration of almost every consonant, and the gutturalization of almost every vowel and diphthong, in which the Anglo-Saxon seems to have

taken such delight. Our terminational system has also been extensively affected by the same influence, and generally with the result of the substitution of a smoother or shorter final syllable. Probably, also, the decay and at last total disappearance of the initial *ge* already noticed may be attributed principally to the same cause; a *g* sounded hard before the letter *e*, it may be remarked, is a combination unknown to the French language, and altogether abhorrent to the genius of its euphonic system. We may consider it fortunate, on the other hand, that that system was not able to force upon us, in compensation for our old guttural prefix, either its nasal *n*, or even its ordinary pronunciation of the vowel *u*.

12. It may be doubted whether the French element at work in it can have had anything to do with the production of that very remarkable feature of our modern English, the *name* sounds, as they may best be designated, of the five vowels. These sounds may be most scientifically defined as those which the vowel always (or all but universally) has when it is the terminating letter of an accented syllable; as in n*a*-tion, m*e*-tre, d*i*-al (or d*y*-ing), h*o*-ly, m*u*-sic. It is from its sound in this position that the vowel takes its name as a letter; *a*, *e*, *i* (*y*), *o*, *u*. These names and sounds (with the exception only of that of *o*) are all peculiar to the English language, at least among the languages of Europe. The sounds, as represented by the letters to which we have attached them, are, it is believed, one and all (except that of the *o*) unknown to either the Celtic, the Germanic, the Latin, or the Slavonic tongues, whether the letters may stand in the position which has just been described, or in any other. With us, on the other hand, although that position is the only one in which they are constant, they are also of common occurrence with the letter in other positions. They constitute, in fact, as has been observed, a distinguishing feature of the language.

13. Yet there is no reason to suppose that they belonged to the Anglo-Saxon, any more than to any other known Gothic tongue. They are probably of

comparatively modern introduction, more recent even, perhaps, than the commencement of the era of what is called Middle English, which is held to extend from about the middle of the fourteenth to that of the sixteenth century. They have never been known to the Scottish form of the English language; in that the vowels have always had their common continental sounds. Even in the English spoken in Ireland the first vowel has not yet generally acquired the name by which it is universally known in England, and the second retains the continental sound in many instances in which the same sound is now the established English pronunciation. All this would seem to indicate that the introduction into the language of that pronunciation must be due to some action to which it has been exposed only in one of its later stages. It is not perhaps impossible, however, that the intrusion of the French element may, through the disorganization or enfeeblement of the original structure of the language which it occasioned, have laid it more open to the new pronunciation, or rather may have led it to seek after the recovery of something of its old coherence by that among other expedients. The mode of pronunciation in question may be not unaptly described as being a tightening or bracing up of that which the vowels have in other languages.

14. And, although the accession of the foreign element does not appear to have been felt by the inflexional system of the language, or that part of its grammar which is technically called the Etymology (unless, indeed, it may have assisted in precipitating its dissolution), the other part of our grammar called the Syntax, consisting of the rules for the connection of words in sentences, must have been to some extent modified by the vocables and forms of French and Latin derivation to which it had to be accommodated. The imported term in many or in most cases would naturally bring its own peculiar government along with it. Many new idiomatic expressions would also be introduced, and, generally, the spirit of expression

which constitutes what is called style would take more or less of a new character.

15. Yet this would affect the written much more than the spoken language. We scarcely, indeed, apply the term style except to what is written. And not only is the system of oral expression, constituting the living fibre of a language, always comparatively unimpressible and indestructible; in the present case, as has probably happened in most similar cases, it was the written style that was more especially exposed to the innovating and revolutionizing influences. The new words that have been making their way into the language from the French and the Latin ever since it entered into partnership, as we may express it, with these foreign tongues, probably about the middle of the thirteenth century, have been mostly imported through books. Many of the first books written in English as distinguished from Anglo-Saxon were translations from the French. And to this hour it is the distinction, as we have seen, of the classic portion of our vocabulary that it is much more largely employed in literature or formal composition than in ordinary colloquial intercourse.

16. The immense difference in spirit and character between the English style of what is called the Anglo-Saxon period and that of later times will be evident on the slightest examination. Even Anglo-Saxon verse, with all its pomposity, inversion, and general elaboration of manner, is constitutionally asthmatic or short-breathed. It is never more than a series of explosions. The want of flow, intermixture, and *callida junctura* in the less pretentious prose is such as to make it resemble the talk of children. The simplicity is such as would suit an index. Composition, in any proper sense of the word, there is none. It is as if there were only one possible way in which anything could be stated or expressed, one set of words, one sequence of propositions or clauses. And it is the same down to the date when the influence of foreign models began to tell upon English writing, which was not till Chaucer rose. We have scarcely anything written before his

day in prose; and the only art discoverable in any verse preceding his is so much as is required to meet, for the most part in the rudest way, the mechanical exigencies of the rhyme or the alliteration. It cannot be said that there is more than this, for instance, either in Layamon, or the Ormulum, or Robert of Gloucester, or Robert de Brunne, or very much more even in Minot, or the author of the Visions of Piers Plowman. English style begins, at the earliest, only about the middle of the fourteenth century.

GEO. L. CRAIK.

CHARACTER OF THE HAPPY WARRIOR.

WHO is the happy Warrior? Who is he
That every man in arms should wish to be?
It is the generous Spirit, who, when brought
Among the tasks of real life, hath wrought
Upon the plan that pleased his boyish thought:
Whose high endeavours are an inward light
That makes the path before him always bright;
Who, with a natural instinct to discern
What knowledge can perform, is diligent to learn;
Abides by this resolve, and stops not there,
But makes his moral being his prime care;
Who, doomed to go in company with Pain,
And Fear, and Bloodshed, miserable train!
Turns his necessity to glorious gain:
In face of these doth exercise a power
Which is our human nature's highest dower;
Controls them and subdues, transmutes, bereaves
Of their bad influence, and their good receives:
By objects, which might force the soul to abate
Her feeling, rendered more compassionate;
Is placable—because occasions rise
So often that demand such sacrifice;
More skilful in self-knowledge, even more pure,
As tempted more; more able to endure,
As more exposed to suffering and distress;
Thence, also, more alive to tenderness.

Tis he whose law is reason; who depends
Upon that law as on the best of friends;
Whence, in a state where men are tempted still
To evil for a guard against worse ill,
And what in quality or act is best
Doth seldom on a right foundation rest,
He labours good on good to fix, and owes
To virtue every triumph that he knows.
Who, if he rise to station of command,
Rises by open means; and there will stand
On honourable terms, or else retire,
And in himself possess his own desire:
Who comprehends his trust, and to the same,
Keeps faithful with a singleness of aim;
And therefore does not stoop, nor lie in wait
For wealth, or honours, or for worldly state;
Whom they must follow; on whose head must fall,
Like showers of manna, if they come at all:
Whose powers shed round him in the common strife,
Or mild concerns of ordinary life,
A constant influence, a peculiar grace;
But who, if he be called upon to face
Some awful moment, to which Heaven has joined
Great issues, good or bad for human kind,
Is happy as a Lover; and attired
With sudden brightness, like a Man inspired;
And, through the heat of conflict, keeps the law
In calmness made, and sees what he foresaw;
Or if an unexpected call succeed,
Come when it will, is equal to the need.
He who, though thus endued as with a sense
And faculty for storm and turbulence,
Is yet a Soul whose master-bias leans
To home-felt pleasures and to gentle scenes.
Sweet images! which, wheresoe'er he be,
Are at his heart; and such fidelity
It is his darling passion to approve;
More brave for this, that he hath much to love:—
'Tis, finally, the Man, who, lifted high,
Conspicuous object in a Nation's eye,
Or left unthought-of in obscurity—
Who, with a toward or untoward lot,
Prosperous or adverse, to his wish or not—
Plays, in the many games of life, that one
Where what he most doth value must be won:

Whom neither shape of danger can dismay,
Nor thought of tender happiness betray;
Who, not content that former worth stand fast,
Looks forward, persevering to the last,
From well to better, daily self-surpast:
Who, whether praise of him must walk the earth
For ever, and to noble deeds give birth,
Or he must fall, to sleep without his fame,
And leave a dead unprofitable name—
Finds comfort in himself and in his cause;
And, while the mortal mist is gathering, draws
His breath in confidence of Heaven's applause:—
This is the happy Warrior!—this is He
That every man in arms should wish to be!

WORDSWORTH.

THE HOPES OF MAN.

For through the lapse of ages may the course
Of moral good progressive still be seen,
Though mournful dynasties of Fraud and Force,
Dark Vice and purblind Ignorance, intervene;
Empires and Nations rise, decay and fall,
But still the Good survives and perseveres thro' all.

Yea, even in these most lamentable times,
When, everywhere to wars and woes a prey,
Earth seem'd but one wide theatre of crimes,
Good unperceived had work'd its silent way;
And all those dread convulsions did but clear
The obstructed path to give it free career.

But deem not thou some overruling Fate,
Directing all things with benign decree,
Through all the turmoil of this mortal state,
Appoints that what is best shall therefore be;
Even as from man his future doom proceeds,
So nations rise or fall according to their deeds.

Light at the first was given to humankind,
And Law was written in the human heart.
If they forsake the Light, perverse of mind,
And wilfully prefer the evil part,
Then to their own devices are they left,
By their own choice of Heaven's support bereft.

What then in these late days had Europe been—
This moral, intellectual heart of earth,
From which the nations who lie dead in sin
Should one day yet receive their second birth—
To what had she been sunk if brutal Force
Had taken unrestrain'd its impious course?

The Light had been extinguish'd—this be sure—
The first wise aim of conscious Tyranny,
Which knows it may not with the Light endure:
But where Light is not, Freedom cannot be;
"Where Freedom is not, there no Virtue is;"
Where Virtue is not, there no Happiness.

SOUTHEY.

END OF THE THIRD BOOK.

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Comprising Poems:—1. Historical and Geographical. 2. On the Love of Home and Country. 3. Of Work and Progress. 4. Relating to the Sea and the Sailor. 5. On the Love of Nature. 6. Of the Imagination and Fancy. 7. Religious and Moral.

The pieces are taken chiefly from the best modern poets; every piece is prefaced by a note—generally selected from the works of standard writers—explanatory of the subject of the poem, and followed by notes and questions, historical, grammatical, philological, and critical, calculated to stimulate the thought and guide the taste of the pupil.

The pieces in this little volume are selected with great care and judgment from the best modern poets. It is, decidedly, one of the most agreeable selections of extracts we have met with amongst the many which have been published for the use of schools from Scott down to its own date. —*Globe.*

This volume has several features. It contains pieces rather than passages; for although some of the selections are not entire poems, they are complete subjects. The selections are judiciously made, principally from modern writers.—*Spectator.*

The selections are of a quality to foster and promote sound taste, and comprise a very large number—perhaps the majority—of the shortest poems that have obtained a permanent standing in our literature.—*Weekly Chronicle.*

There is a novelty of design in this book. It is very well adapted for reading in schools.—*Critic.*

We certainly have made great progress in a right direction since the period of Enfield's "Speaker." For schools and private reading the volume will be found most acceptable.—*Church and State Gazette.*

As a whole, we can say that we have not met with a better book for the use of advanced pupils in school, or for private reading, than Mr. Hughes's Selections of English Poetry.—*Morning Advertiser.*

The selections of English Poetry are well adapted for the use of schools. The cause of sound education is materially served by such compilations as these.—*Morning Post.*

It is a selection made upon a principle and by a really able man.—*Guardian.*

The editor of this compendious little work for schools has based it upon the intellectual system as regards education, in contradistinction to the system of learning by rote. He acts in this respect upon the *dictu* of Dr. Arnold, namely, that it is our wisdom as well as our duty to cultivate the faculties of youth, each in their season, "first the memory and the imagination, and then the judgment." Most of the poems are of the first order, and well known in the English tongue; and the book, therefore, cannot fail, as a whole, to be popular in schools and among the class of readers for whom it is more especially intended.—*Observer.*

This work is worthy of Mr. Hughes's high reputation as a scholar and public teacher. Various educational works, prepared by him for his school at Greenwich Hospital, are in general use and this manual of English poetry deserves equal popularity. The leading peculiarity of the volume

is the plan of introducing every poem with a prose piece from some good author. In general also the poetical pieces are entire, so that it is a book of selections, not of extracts. Many modern pieces, American and English, are introduced, not hitherto found in school-books, but deserving to be classed with the old familiar poems. The notes, questions, exercises, and concluding vocabulary, render this a most convenient as well as valuable educational class-book.—*Literary Gazette.*

We have rarely seen a book of its unambitious character got up better, with more taste, judgment, and ability, than the selection of English Poetry. Both the poetry and prose introductions prove that Mr. Hughes has read extensively, and with discernment, the best authors in our tongue, for not only is the book highly desirable as a school-book, but the adult of accomplished mind and culture may take it up at any time, and find it a temporary intellectual treat. It furnishes most agreeable desultory reading, and refreshes the memory with glimpses of the best authors.—*British Times.*

Mr. Hughes, deserves great praise for the care with which the poems in this volume have been selected and edited. For schools and private families he has published a most useful work. We have fewer stock pieces, and more original selections, than generally is the case in works of this kind.—*Standard of Freedom.*

This is a very valuable addition to the class of books to which it belongs. It comprises Introduction, Notes, and Questions, together with an appendix of Greek, Latin, and Saxon roots; and constitutes decidedly the best book of it's class that has yet appeared. Mr. Hughes, we have had occasion once and again to bring before our readers as an accomplished instructor of the young, and a superior writer of school books. As Head Master of the Royal Naval School of Greenwich Hospital, he has most worthily asserted the prerogatives of his high office, and done great credit to those he serves. The first Section is headed, Historical and Geographical; the second, Home and Country; the third, Work and Progress; the fourth, Sea and the Sailors; the fifth, Love of Nature; the sixth, Imagination and Fancy; the seventh, Religious and Moral. Under all these heads we have exquisite selections from our best writers of past and present times; finely exemplifying the adage of Dr. Arnold, that "the very essence of Poetry is that which exalts and ennobles us, and puts us into a higher state of mind than that which we are commonly living in." But it will be a great mistake to suppose that it is only a work for the young; it is a work for all. The first men and the first scholars of the realm may while away most pleasantly and profitably many a leisure hour; while the literary apparatus interspersed through the volume, and the Appendix, will be greatly helpful to even the well-informed in general history. It is a capital book.—*British Banner.*

This is a very pretty school-book, well selected, well compiled, and admirably fitted for general use. We can have no doubt, therefore, of its success.—*Glasgow Courier.*

We have seen many poetical selections and extracts for the use of schools, but few equal, and none superior, to this.—*Edinburgh Witness.*

The volume of "Select English Poetry" is a perfect treasure—a repertory of the best lyrical pieces in our language. We are much mistaken if it be not accounted such by "children of a larger growth" than schoolboys.—*Whitehaven Herald.*

This is the best selection, of the most eminent English poets, which has yet come under our observation, eminently calculated as it is from its arrangement to improve the youthful mind, as well as to impart pleasure to those of maturer years. Mr. Hughes is too well known in the paths of

elegant and useful literature to require a lengthened notice of any work proceeding from his pen. The present publication we would strongly recommend.—*Waterford Mail*.

This book comprises a selection of poetical gems, the productions of the best English writers. The work is one which we highly commend, and we know no other better adapted for companionship in a rural ramble.—*Somerset County Gazette*.

This is one of the most valuable educational books which has lately come under our notice. Its object is the cultivation of the imaginative as well as the intellectual powers, to nourish the memory, to encourage the imagination, and to discipline the judgment. With an amount of labour which is almost incredible, the Editor has here furnished, not only some hundreds of excellent poems, which are of themselves calculated to enliven the intellect, enhance the store of knowledge, and correct the taste, but has prefixed to each an appropriate prose piece which is further adapted to the bringing out a feeling of love and admiration for the beautiful, and has appended an etymological table of Greek, Latin, and Saxon roots.—*North Wales Chronicle*.

Of the contributors to Educational Literature, Mr Hughes may be deemed among the most careful and perfect. He does manage to write books which please the learner and delight those who have to superintend the work of Education. The book before us is a charming one—so small that it will not incommode the pocket, yet full of valuable selections.—*The Welshman*.

This is a very useful volume of select English poetry, with prose introductions, notes, and questions. Considerable taste has been displayed in the selection, which consists of almost all the best short poems in the language. As a whole, the work is worthy of the most extended patronage.—*Windsor Express*.

The volume of Selections in Verse may be used with advantage. The pieces are extracted from our best poets, and each is introduced by a prose quotation, appropriately chosen from some standard writer. They will serve the double purpose of either being committed to memory, or used as reading lessons.—*Edinburgh Advertiser*.

The design of the elegantly got-up little volume now before us is to adapt the best specimens of the principal British poets to the instruction of youth, in the same way as the poetry of classic times has been made. There can be no doubt that great advantages might be attained by directing and purifying the taste of young persons in schools through a judicious intercourse with the works of the principal English and American poets, provided that they were not forced upon the mind, as under the old system Greek and Latin poetry has been, until the only result attained was the impression upon the scholar of a fixed and unalterable distaste for the glorious models of genius and style which had been made his task and his punishment while at school. The present volume contains from two to three hundred pieces of poetry, principally selected from the works of this and the past age, and each prefaced by an appropriate motto of argument taken from some prose author of eminence On the whole the book is one of considerable value, and, from the excellence of the selections, will be found of much use not alone to the student but to readers of matured age and refined taste.—*Cork Examiner*.

Here is a great improvement on the English Reader, the Speaker, and other books of that class intended for the improvement of youth. There are few persons who will deny that the imaginative, as well as the intellectual and imitative powers of the young, should be cultivated; and we believe that the former exercise the greatest influence in softening the

temper, refining the manners, and enlarging the mind. For these purposes there is nothing more efficient than genuine poetry, by which youths are rendered familiar with high thoughts expressed in appropriate language. We therefore welcome Mr. Hughes's volume as an aid in the cultivation of the imaginative powers, as calculated to excite the social sympathies and a love for the beautiful in nature and art. In carrying out a comprehensive design, he has produced a work far surpassing anything similar in character, and fully answering the purpose which he had in view.—*Norfolk Chronicle.*

The plan of this work is a decided improvement on the old system of preparing selections of poetry for the use of schools. The selection has been made with great care and judgment, and not only to the teacher and the private student, but to parents and general readers, the volume will be found of vast service in the work of education and private improvement; "the best thoughts," as the preface says, "in the best language will be rendered familiar to them, and indelibly impressed on their memory; their sympathies will be called forth and properly directed, and their taste at once elevated and improved."—*Liverpool Chronicle.*

Mr. Hughes has selected a body of poetical pieces upon various subjects, and of various degrees of excellence, each of which he introduces with a prose piece, and appends questions on etymology, syntax, history, &c., which seems to us well fitted to test a boy's knowledge. The book is a very neat one, and independent of its educational purpose, presents a good collection of British and American poetry.—*Cambridge Chronicle.*

XI.

Just published, price 4s. 6d.,

SELECT SPECIMENS of ENGLISH PROSE,

FOR THE USE OF SCHOOLS AND PRIVATE READING;

Comprising Pieces relating to:—1. Natural History and Geography. 2. Biography and Civil History. 3. Education and the Progress of Society. 4. The Sea and Maritime Adventure. 5. The Imagination and Sympathetic Affections. 6. Science and General Knowledge. 7. Religion and Morals. Small Octavo.

*** This book is intended to be a companion volume to the "Select Specimens of English Poetry." The selections are in a great measure from modern works, many of which have not hitherto been introduced into School Books. Though the bulk of the work is prose, yet a few congenial poetical pieces have been interspersed to give variety to the readings. In the volume of Poetry, the prose is subordinate; but in that of Prose, it is the poetry that takes the second place. In each, however, the one throws light on the other.

"The distinguishing feature of this selection is the practically instructive spirit which has guided the compiler's choice of specimens without losing sight of the elevated and the philosophical. The older 'readers' were purely literary; not only was excellence in composition the first thing thought of, but it was almost the only thing; historical information, or moral or religious instruction, coming as it were by the by. Mr. Hughes has proceeded upon a different principle. Literary merit is not forgotten, but the subject and the matter, sometimes in reference to the affairs of life or the questions of the day, are also considered. Adam Smith, for example, is quoted, and Robertson's 'Disquisition on Ancient India' contributes views on commerce; modern travellers and cosmogonists are laid under contribution for geographical pictures or information; a 'part' of the book is devoted to education; and those extracts which have a more

general character turn upon events or men of the century. The technical points—questions, etc.—are well done."—*Spectator*, June 4, 1853.

"This work is intended as a companion volume to the author's 'Select Specimens of English Poetry.' The selections are in a great measure from modern writers. They are arranged under various heads. To give variety to the reading, a piece of poetry is occasionally given in further illustration of the subject to which the prose extract relates, in the same way that short passages of prose are introduced in the volume of poetry. Explanatory notes and questions are added to each extract, and there is an etymological appendix to the whole. The choice of pieces shows much discrimination and taste. This work will introduce new material for reading into our schools, in which for a long time the same staple pieces have been read over and over again, until they have become entirely hackneyed and void of freshness and novelty. Even adults may take up the book and peruse passages here and there with great interest. The selection is characterized by great variety, both in the subjects and the authors. The list of authors comprises nearly all the great names in our modern prose literature, including many living writers. There are some well-culled passages from Macaulay. We also notice some excellent extracts, both scientific and educational, from the writings of Professor Moseley, and some educational ones from those of Sir James Kay Shuttleworth."—*Educational Expositor*.

"This is intended as a companion to the author's excellent *repertoire of Selections of English Poetry*, which we have before had occasion to commend, in common with the other numerous works which the active master of the Naval School has published. These selections are well arranged and judiciously chosen, so as to combine instruction and amusement."—*Britannia*.

"Books of this description are of great scholastic utility, for they materially help in forming the taste while conveying valuable information in a pleasing variety of forms. Such a selection, too, requires considerable judgment, large experience of the wants and inclinations of scholars, and familiarity with the best examples of contemporary literature. The explanatory notes and questions, the selection of the difficult words, and the etymological appendix of Greek, Latin, and Saxon roots, add materially to its teaching value, and render it we" worthy of the reputation of so esteemed a provider of school-books. We have no doubt of its obtaining as wide a circulation among schools as the author's 'Select Specimens of English Poetry,' to which it forms a necessary companion."—*Educational Times*.

"This selection consists of about three hundred pieces of prose, interspersed with choice illustrative pieces of poetry. The plan of the book is to arrange the readings under the respective heads of subjects. Thus, there is about an equal number under 'Geography and Natural History,' 'History and Biography,' 'Education and Progress,' 'Sea and Maritime Adventure,' 'Imagination and Sympathetic Affections,' 'Science and General Knowledge,' and a double portion under the head 'Religious and Moral.' Words of difficulty or peculiarity are selected from the lesson and placed at the top for grammatical, derivative, and exegetical exercise before commencing the reading, while at the end of the lesson a moderate number of questions and explanations is appended, calculated to lead the reader to a more thorough comprehension of the matter. The etymological appendix is very useful for the scholar's private study in connexion with the lessons. This book is one of the most useful of Mr. Hughes's series of school books, and is worthy of general use. It is the best school selection we have seen."—*English Journal of Education*.

"The educational works of Mr. Edward Hughes must now, we should think, have found such general acceptance that the appearance of an

addition to the series can require only to be known to secure for it also a large circulation. The present work is constructed on the same careful and systematic plan as the others, and includes specimens of most of our recent prominent English writers, as well as of the standard authors on whom the compilers of old school collections were wont to draw."—*Scotsman.*

"By this book Mr. Hughes confers another obligation upon the teachers of youth; few of the standard authors of our literature escaping the levy. Of the general arrangement, it will suffice to say that it appears to secure the comprehension and sympathy of the pupil, and suited to beget in his mind a thirst for reading."—*Weekly News and Chronicle.*

"This is a companion publication to the specimens of poetry recently published by the compiler, and reviewed in the columns of *The Observer* on its first appearance. The authors drawn upon are chiefly Barrow, Hooker, Taylor, and the higher class of thinkers on morals. The appendix contains a complete list of the roots of English words. As a school-book, therefore, this work cannot be surpassed."—*Observer.*

"This work, as its title implies, consists of selections from the production of English authors, which are classified under various sections. Its object is to instil into the youthful members of society a taste for reading, whereby they may obtain that information which they are usually forced to learn dogmatically. The selections are chiefly from the best writers of modern times, are from their variety well calculated to enlist the attention of the young, and at the same time to supply them with a vast amount of useful information."—*Exeter and Plymouth Gazette.*

"Mr. Hughes, the editor of the above selection of English prose, is already honourably known as a valuable contributor to our educational literature, and the present able and judiciously selected work will be received with much pleasure by the instructors of youth. The great prose writers of England are too little studied by the youth of this country, and Mr. Hughes's publication comes most seasonably to encourage that important study. Some of the greatest writers have been laid under contribution in order to enrich the work, and every subject has been suitably and usefully introduced. We strongly recommend this volume as the very best of its class, and is as well fitted for private reading as for the use of schools."—*Port of Portsmouth Guardian.*

"Mr. Hughes has steadily risen in public estimation as a compiler of school books. True that his industry is unflagging and the works from his pen are now numerous. But neither industry nor voluminousness will stand in the stead of excellence and appropriateness. Mr. Hughes's books are both excellent and appropriate, and hence his progress toward fame and his secure attainment of reputation. He has avoided the blunder too common, nay, almost universal, of conveying to children trivial thoughts in silly phrases. He has sought rather to convey the elements of thought —facts:—the elements of refinement—appropriate words and cultivated expressions. Thus has he interested those who have had recourse to his books rather than pandered to them; thus has he led them on from the admiration of harmonious words, the music of language, to the love of information. As we have before spoken highly of Mr. Hughes's elementary books of geography and other branches of instruction, and as we welcomed his volume of selections from the English poets, so now we as heartily thank him for the little book before us, to which it is intended to be a companion. As usual in his selections, Mr. Hughes has placed at the commencement of each lesson words for grammatical and exegetical exercise before the reading is commenced. Mr. Hughes has also added an appendix of Greek, Latin, and Saxon roots. Pupils and schoolmasters should at once add this volume to their stores."—*Welshman.*

"We certainly do not know a better book of its kind 'for the use of schools, or private reading;' there are few so good."—*North Wales Chronicle.*

"We can congratulate Mr. Hughes on the admirable and judicious taste which he has exercised in laying under contribution the best standard authors on a variety of useful subjects—educational, social, religious, and moral questions being adequately illustrated. An interesting feature in the work is that the leading words occurring in treating of any subject, are singled out and placed at the head of the article, so that the student may undergo a grammatical and exegetical exercise upon them previously to perusal. This is an excellent feature. An appendix specially adapted to the selections is prefixed; and Mr. Hughes's substantial contribution to our literature we can specially recommend for the use of 'schools and private reading'—the object the compiler's labours are intended to serve."—*Leeds Times.*

"Mr. Hughes is the author of several excellent school-books, and his selection of prose specimens is made with a degree of judgment and care worthy of his high reputation. It is distinguished by the same general features of usefulness which have rendered his 'Select Specimens of English Poetry' a well-known book; and we cannot doubt that this companion volume will meet with an equally favourable reception."—*Morning Post.*

"This is a companion volume to the 'Select Specimens of English Poetry,' published recently by Mr. Hughes, for the use of schools and for private reading. In the selection of prose there is room for even more diversity of taste and of judgment than in the case of poetical extracts. The present work contains a great number and variety of pieces, judiciously chosen, skilfully arranged, and adapted for educational purposes. The notes, exercises, and etymological appendix of roots of words, add to the practical usefulness of the volume, which is another valuable contribution made by Mr. Hughes to our school literature.—*Literary Gazette.*

"The head-master of the Royal Naval Lower School has already achieved a reputation for educational works, and although as the title of the work indicates, there is nothing original in this, except the compilation, this little book deserves to find its way into the hands of many scholars."—*Sherborne Journal.*

"If we could lay claim to the honourable position of Paterfamilias, we should feel ourselves under considerable obligations to Mr. Hughes for his placing under our disposal his admirable compilations. We do not think that as elementary educational works they could be surpassed, and yet they contain a great amount of information which is highly interesting and important to adults. We conclude with a commendation of the volume alike to sire and son; the one it will pleasantly remind of bygone excursions in the fields of literature, and the other it will introduce to an acquaintance with, and love for, their beauties, fostering a taste for reading, and pointing out the best subjects for the indulgence of its pleasures."—*Derbyshire Advertiser.*

"The selections are generally from standard authors, chiefly modern; and are made with great taste and judgment. They are also accompanied by explanatory notes, and by an Etymological Appendix, prepared with great care; in which facts, dates, definitions, and even illustrative quotations are given, so as thoroughly to attract and inform the young student. Some poetical pieces are interspersed throughout the volume, which lead pleasantly into the themes of the prose. There was no such book when we were at school,—the *Speaker*, was the all-in-all: and we do not think the value of such a work consists chiefly in its attractiveness and usefulness as a class reading-book, but in its fitness to awaken a love of reading, to form pure and elevated tastes, and to direct into the paths of literature.

These objects Mr. Hughes's volume will assuredly serve, no less than it will banish the tedium of the reading-class and aid the efforts of a sincere and intelligent teacher. We have no lingering doubt when we add, that it is a book boys will be quick enough and glad enough to seize when *out* of the schoolroom; and which working-men and other readers with a limited number of books will regard as a small treasure.—*Nonconformist.*"

"This work is designed to be a companion to the author's admirable work entitled, 'Select Specimens of English Poetry.' The greater part of the work is prose, though, for the sake of variety, a few poetical effusions are interspersed. The author has made a wide and judicious selection, and produced a book which older heads than those at school may peruse with profit. The work has our hearty and unqualified approbation."—*Glasgow Examiner.*

"Mr. Hughes has already published a number of very valuable school books, some of which we have previously noticed. The volume before us displays the same care and judgment that we had occasion to commend in the other works put forth by him. The selections are chiefly from modern writers of high reputation. Most of the standard authors of English literature have been laid under contribution, and the result is, that we have presented to us some of the most beautiful passages from most of the popular works of the day. The extracts are not confined to prose. Several poetical pieces are interspersed with a view to give variety to the readings. The volume contains an immense amount of useful information. We quite approve of the plan of selecting the religious extracts from such writers as Hooker, Barrow, Taylor, &c. The etymological appendix of Saxon, Greek, and Latin roots, with miscellaneous facts, dates, and definitions incorporated, will be found very useful. We can cordially recommend this work to the notice of teachers."—*Blackburn Standard.*

"Mr. Hughes seems to have devoted his energies in the preparation of a series of new educational works, equally for the use of schools as for reading and reference in private families. His abilities for the task he has undertaken as the instructor of youth, or in the preparation of class-books, which, although they may be primarily intended for advanced pupils, yet will constitute standard works for scholastic and private libraries. The book before us is just one of this character, the beauties of the prose being still more displayed by the succinct and well-arranged explanatory notes and questions appended. The work extends to five hundred and twenty-eight pages. When it begins to be looked into, it will be found, from its judicious selections of 'the best languages' admirably adapted for the great work of educational progress, and eminently calculated to secure intellectual advancement generally."—*Stockport Advertiser.*

"The style and arrangement of this work are similar to the admirable 'Selection of English Poetry' by the same hand; the pieces are exceedingly well selected, and are chiefly from modern writers on a great variety of subjects, religious and moral education, and progress, science, and history, &c.; thus affording to both teachers and scholars a novel and interesting course of instructive reading; several poetical compositions are also introduced. We think the volume is calculated for extensive usefulness, and that it will fully carry out the intention expressed by its talented compiler in his preface, namely, 'Not merely to amuse, but to instruct; to attract the young, and to inspire them with a love of reading which shall accompany them through their future course, and be an ornament and protection to them through life."—*Bath Herald.*

"Mr. Hughes is favourably known to the public by the numerous educational works he has published, some of which have been noticed in our

columns. The volume before us is a very excellent reading-book, consisting of upwards of five hundred pages of prose extracts, interspersed with a few congenial poetical pieces. The passages are selected with care, include extracts from modern writers who have not figured in the ordinary school-books, and care has been taken to cull those which shall have an elevating tendency on the mind of the pupil. Notes and questions, and an etymological appendix add to the utility of the volume."—*Bristol Mercury.*

"This volume recommends itself above former English Readers, chiefly by the modernness of the selection, and the much greater interest and variety of its subjects, all the best writers of the day having been laid under contribution to furnish it with choice passages. We are mistaken if both schoolboys and masters will not have recourse to it in play hours as well as for their lessons. In the moral and religious sections, extracts from the fine old divines Barrow, Taylor, and others, are wisely preferred, as likely to fortify the taste against declamatory writers of the present day."—*Coventry Herald.*

"This is a book of the class denominated in our schoolboy days 'An English Reader,' comprising selections from the best authors in the language, designed to store the mind and memory with valuable historical and general information, and to accustom the ear and eye to a chaste, correct, and vigorous style of composition. The work constitutes a very excellent and judicious compendium, embracing great variety in its scope and character, singular felicity in its arrangement and plan, and including, not merely the usual 'stock pieces' of similar productions, but several copious extracts from popular and standard writers of this and the preceding age. Although chiefly prose, yet some poetical pieces are introduced, which relieve the whole, and will prove the most agreeable and attractive portion to youth. Instead of the usual method of an index, giving the various authors whose productions have been chosen, there is a list of contents, indicating the subjects of the several papers, so that the teacher or reader has only to turn to this to find a lesson or theme in accordance with his views or purpose. The names of the authors are affixed to the end of each selection. Words are placed at the beginning of the several papers for grammatical and exegetical exercise before the reading is commenced; explanatory notes are furnished where the text requires such; and in an appendix, there is given a complete list of the roots that enter into the English language, facts, dates, and definitions being also interspersed in this most useful department of the volume, Mr. Hughes justly remarking:—'Mere vocables are found to be dry and repulsive; but by adorning the path of learning with the flowers of poetry, and using all available means to amuse, we may be able to attract the young, and inspire them with a love of reading, which shall accompany them in their future course, and be an ornament and protection to them through life.' The work is, of course, intended principally for schools, but its value will be felt and appreciated in families: indeed it is adapted for general perusal and study."—*Newcastle Guardian.*

"This is one of the best books of the kind we have seen, and a great improvement upon the 'Readers and Speakers' of our own schoolboy days. The selections are principally from the most brilliant and popular modern writers, as well as of course, the most distinguished of the great authors of the last century. The extracts are made with much taste—the explanatory notes and questions and the etymological appendix are adapted to awaken thought and convey instruction—and the work, as a whole, is admirably calculated to excite in the minds of the young, for whose use it is especially intended, a love of reading and a thirst for knowledge."—*Nottinghamshire Guardian.*

"Mr. Hughes has exercised a just discrimination in the selection, considering not only literary merit, but soundness of information and elevation of sentiment. He has endeavoured successfully, we believe, to link together entertainment and instruction, and the book is superior of its kind to anything that has hitherto come under our observation. The questions and explanatory notes are concise and to the point."—*Worcestershire Chronicle.*

"These selections are in a great measure from modern writers, and have been adopted with a view of giving variety to the readings. The selections are made from the works of first-rate men, such as Stewart, Scott, Everett, Coleridge, Porter, Moseley, Giffard, Horne, Chalmers, &c. The essays are beautiful specimens of English composition, and form a fund of instruction and amusement."—*Reading Mercury and Oxford Gazette.*

"The object of the talented author of this work is to render it useful for schools and private reading, and a fit companion volume to his 'Select Specimens of English Poetry.' The bulk of the volume is prose, but it is, at the same time, interspersed with a pleasing variety of poetical pieces of the first order. In the moral section of it, the author has drawn largely from our older and standard divines, being of opinion 'that any youth, who is made thoroughly to comprehend and appreciate extracts from Hooker, Barrow, Taylor, and such class of thinkers, will not readily yield his judgment to declamatory writers of the present day.' In this respect the author has exercised a judicious judgment; and we hope his object will be attained, for, as he truly observes, the false and superficial knowledge 'that leads to bewilder and dazzles to blind,' will be best corrected, not by keeping men in total ignorance—for that, happily, is no longer possible—but by imparting the fullest information on every subject on which they are inclined to think. On the whole, we regard this book not only eminently useful to schools, but containing, as it does, a fund of the most varied information, highly valuable to the general reader, and in every way calculated to add to the already well-earned reputation of the author."—*Cambrian.*

"We have often had occasion to notice the educational works of Mr. Hughes, as being of a high and eminently useful character. Here is another of them: a whole course of literature comprised in one compact little volume, and the matter so arranged under heads that the reader may in a moment gratify the bent of his mind. Under general heads, an immense number of the best passages in our best authors are collated, and whoever takes up this book will find it difficult to put it down again. Whether for reading in a social circle or in a school, it is equally admirable."—*Brighton Herald.*

"This is a work intended for the use of schools and private reading. Its arrangement and plan are excellent; the selections good; and the etymological appendix which is added will be very useful, and doubly acceptable to the private student. This work will add to the already fair fame of the author as an educational writer. We trust its success will be such as its merit deserves."—*Wakefield Journal.*

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divided into seven sections, each being made up from a different class of subject matter, giving it a method not always found in compilation of so miscellaneous a character, and the variety of pieces under each head, in some fashion, serves the purpose of a regular treatise. Though professedly for schools, children of a larger growth may turn over its pages with pleasure and profit, and, upon the whole, it must be pronounced one of the best books of the kind yet published."—*Kendal Mercury*.

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